Application ID 13-1544634 Injection Molding Machine M&V Report

August 5, 2016

Duke Energy Carolinas
139 East Fourth Street
Cincinnati, OH 45201

The Cadmus Group, Inc.
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Prepared by:
Dave Korn
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Introduction

This report addresses M&V activities for one retrofit energy conservation measure (ECM) as part of the [redacted] Smart $aver custom incentive program application; specifically, the replacement of one injection molding machine.

ECM-1—Injection Molding Machine Replacement

The customer manufactures injection molding products. Injection molding machines—also known as presses—mold polypropylene resin into various exterior building products. Press sizes range from 44 tons to 3,000 tons.

This retrofit project targeted a 1996 Van Dorn, 500-ton hydraulic press, replaced with a Sumitomo Systec 420, 506-ton hybrid press, which operates more energy efficiently and is intended to increase productivity.

Goals and Objectives

Table 1 shows projected savings goals identified in the project application.

Table 1. Project Goals

Applicant		Duke Energy		
Annual kWh Savings*	Avg. kW Reduction	Claimed Annual kWh Savings	Claimed Coincident Peak kW Reduction	Claimed Non-CP kW Reduction
48,427	9	135,308	22	22

* The application energy saving estimates provided to Cadmus appear to have been incomplete, since they are significantly lower than those ultimately claimed by Duke Energy for program tracking.

The M&V project sought to verify actual numbers for the following:

- Facility peak demand reduction (kW)
- Summer utility coincident peak demand reduction (kW)
- Annual energy savings (kWh)
- Annual realization rates (kW and kWh)

Project Contacts

The Duke Energy contact listed in Table 2 granted approval to plan and schedule the site visit for this M&V effort.

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Table 2. Project Contacts

Organization	Contact	Contact Information
Duke Energy	Frankie Diersing	p: 513-287-4096 Frankie.diersing@duke-energy.com
Cadmus	Christie Amero	p: 303-389-2509 christie.amero@cadmusgroup.com
Customer	redacted	

Site Location/ECM Location

The location where this measure was installed is shown in Table 4.

Table 3. Project Location

Address	ECM
redacted	1

M&V Option

To assess this project, Cadmus utilized IPMVP Option A.

Implementation

Cadmus reached out to the site contact provided by Duke Energy to review the evaluation plan and to schedule the site visit. The site contact confirmed that the equipment was served by 480V and the meter installation could be performed de-energized. Christie Amero and Tom Davis of Cadmus performed the site visit on January 8, 2016.

Field Notes

During the site visit, Cadmus met with the site contact to review the metering plan and to collect general operating information.

The site produces various plastic parts for building construction (e.g., basement vent grills, drains, tool box organizers). Production typically slows in December and January due to fewer construction projects during those months.

The facility—typically operating 24 hours per day, Monday through Friday—runs four days per week (Monday–Thursday) during December and January. Operation ramps up from May to October, and the site operates six days per week (Monday–Saturday) 75% of the time during those months.

The 13 injection molding machines on site range from ~100 tons to 500 tons, with most of the smaller machines all-electric.

The new, 500-ton hybrid press, which can make up to 100 different parts over the course of the year and utilizes ~20 different materials (e.g., polypropylene, polystyrene). Recently, the machine produced a ~2-pound basement vent grill and a ~5-pound tool box organizer.

The new machine currently has no trend points in place.

Field Data

Table 4 shows product data that Cadmus collected for the installed injection molding machine included in the application.

Table 4. Installed Equipment Nameplate Data

Equipment ID	Make	Model #	Serial Number	Capacity, tons
500-ton Hybrid IMM	Sumitomo DEMAG	SYSTEC 460/820-3300	8073-0099	500

During the site visit, Cadmus photographed the injection molding machine and associated nameplate: Figure 1 shows the installed, 500-ton, injection molding machine; Figure 2 shows the nameplate.

Figure 1. Installed 500-ton Injection Molding Machine

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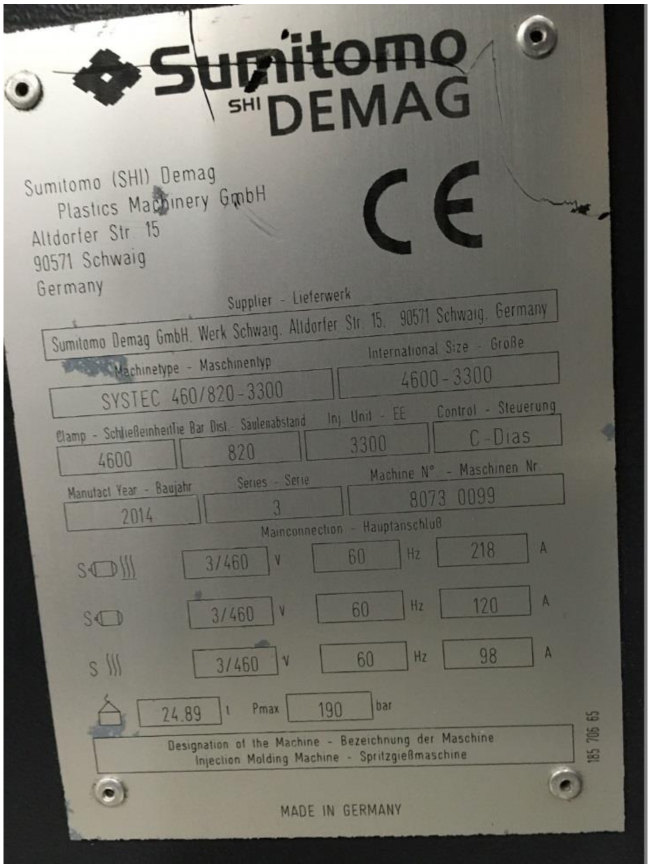
Figure 2. Injection Molding Machine Nameplate



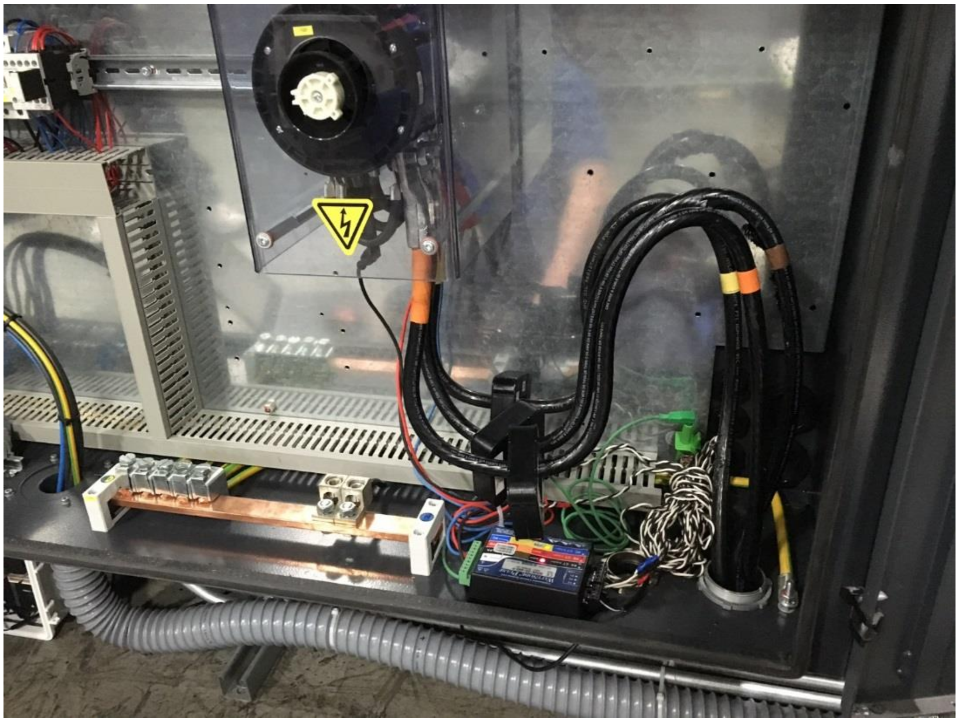
The site contact described parts the machine currently produces and stated the site would run one part through the machine during the metering period; hence, the weight and cycle time of this part would be representative of the average part the machine would make during the year.

Cadmus installed one, three-phase, electric power meter on the injection molding machine, collecting data for two weeks at one-minute intervals. Table 5 summarizes the installed metering equipment, and Figure 3 shows the power meter installation in the injection molding machine.

Table 5. Summary of Installed Metering Equipment

Equipment ID	RX3000	WattNode 3D-480	Current Transducers (Qty/Size)
500-ton IMM	1	1	3 / 400 A

Figure 3. Injection Molding Machine Power Meter Installation



During the meter removal, the site contact provided a summary of part data and machine throughput during the metering period. The mold that the machine ran during the metering period produced two grills and two slides per shot for a foundation vent. The slide was assembled into the grill, so two complete parts were made per shot. The material used was 20% talc-filled polypropylene. The shot weight of 1.168 kW included the weight of the runner, a narrow channel in the mold that moves the plastic from the center point to various areas of the part. Completed parts weigh 0.53 kg.

Table 6 summarizes machine operations and production parameters.

Table 6. Summary of Machine Operation and Production Parameters

Parameter	Value
Run Hours	158 hours, 4 minutes
Material	20% Tac-Filled Polypropylene
Cycles Completed	9,748
Cycle Time, s	58.4
Material Used, kg	11,393.45
Shot Weight, kg (includes runner)	1.169
Cavities per Mold	4 (2 2-piece parts per mold)
Part Weight, kg	0.53

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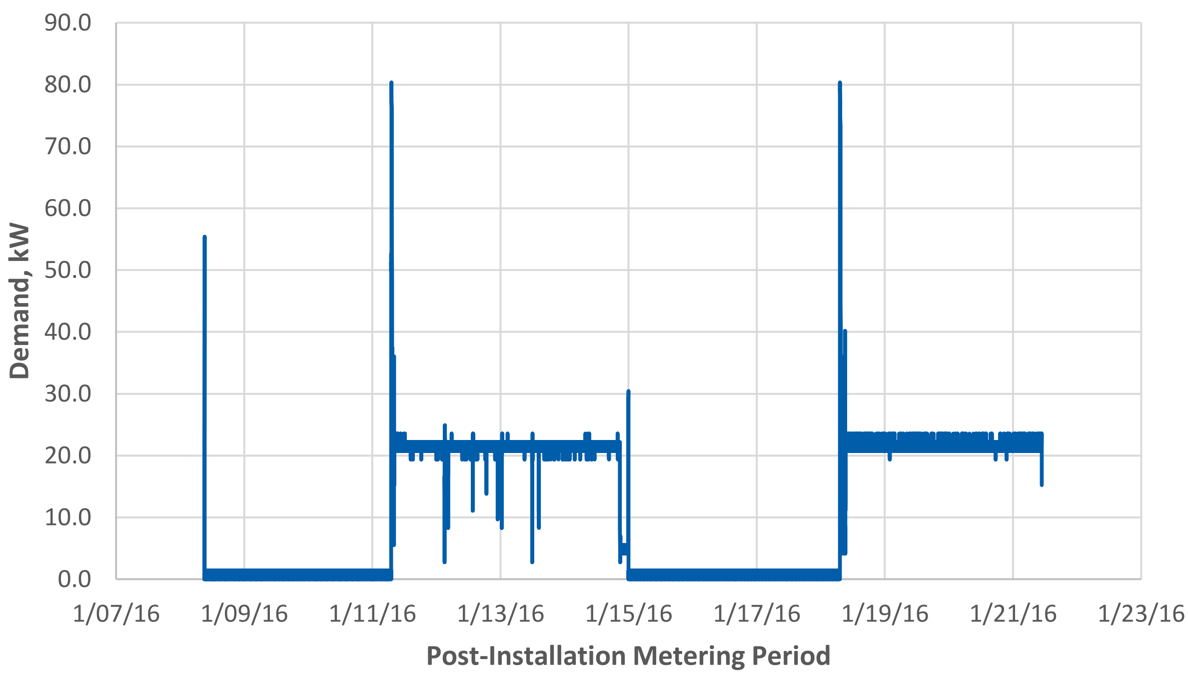
Figure 4 shows the machine's control panel output, including the material type, number of cycles, part shot weight, and number of cavities per mold. Figure 5 summarizes metered demand data during the metering period.

Figure 4. Injection Molding Machine Power Metered Data

Figure 5. Injection Molding Machine Power Metered Data



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Data Accuracy

Table 7. Metering Equipment Accuracy

Measurement	Sensor	Accuracy	Notes
Current, amps	Magnelab CT	±1%	Recorded load must be < 130% and >10% of CT rating
Power, kW	WattNode	±1%	—

Data Analysis

Cadmus used the post-installation metered data to verify the power demand and operating hours of the installed, hybrid, injection molding machine.

Based on the metered data, the machine's power demand averages 20.95 kW when producing parts. When not running (Fridays and weekends during the metering period), the machine has a power draw of ~1.46 kW. The metered energy use rate was 0.31 kWh/kg.

Using the site's monthly operating hour projections, Cadmus calculated installed annual energy use of 139,438 kWh, including energy use during nonproduction hours. Annual demand averaged 15.9 kW; summer coincident peak demand was 21.0 kW.

As a baseline for the measure, Cadmus used a preexisting, 500-ton, hydraulic, injection molding machine. Baseline machine power demand and operating hours had been metered during the original project analysis, and the methodology appeared accurate. Cadmus' evaluation consequently used the hydraulic, machine-metered data. Average operating demand was 41.73 kW. These data did not include power demand for non-operating hours. The metered data can be found in: 'CSN13-1544634 Production Numbers - #8 500T – Sept_Oct_13 (3)' Excel workbook.

Using the same operating hours as the installed case, evaluated baseline annual energy use was 271,196 kWh. Average demand was 31.0 kW, and summer coincident peak demand was 41.7 kW.

The measure produced evaluated annual energy savings of 131,758 kWh, with an average (or non-coincident) peak demand reduction of 15.0 kW and a summer coincident peak demand reduction of 20.8 kW.

Conclusion

Cadmus found the equipment installed as expected. The installed case metered demand data closely matched data collected for the installed machine in the original study.

The measure produced an overall energy savings realization rate of 97%, compared to Duke Energy claimed savings, a summer peak demand realization rate of 94%, and an average (or noncoincident) demand reduction realization rate of 68%. The original analysis assumed the noncoincident demand reduction equaled peak demand reduction and did not account for nonproduction hours.

Table 8 provides a comparison of the applicant, Duke Energy claimed, and evaluation energy savings and demand reduction.

Table 9 provides the realization rates compared to the energy savings and demand reductions claimed by Duke Energy.

Table 8. Comparison of Applicant, Duke Energy Claimed, and Evaluation Energy Savings and Demand Reduction

Applicant		Duke Energy Claimed			Evaluation		
Annual kWh Savings	Avg. kW Reduction	Annual kWh Savings	Coincident Peak kW Reduction	Non-CP kW Reduction	Annual kWh Savings	Coincident Peak kW Reduction	Non-CP kW Reduction
48,427	9.0	135,308	22.1	22.1	131,758	20.8	15.0

Table 9. Energy Savings and Demand Reduction Realization Rates

Annual kWh Savings	Coincident Peak kW	Non-Coincident Peak kW
97%	94%	68%

Application ID 14-1645298
Lighting
M&V Report

August 26, 2016

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The Cadmus Group, Inc.

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Introduction

This report outlines Cadmus' measurement and verification (M&V) activities for one retrofit energy conservation measure (ECM) included as part of the [redacted], Smart $aver custom incentive program application—specifically for replacing halogen parabolic aluminized reflector (PAR) lighting fixtures with LED lighting fixtures. Energy savings were expected to result from the reduced fixture input wattage and reduced fixture quantities. A description of the ECM as submitted in the original application documentation is provided below.

ECM-1: Replace Halogen Lamps with LED Lamps

Pre-Retrofit: [redacted] is a large furniture retail store, located in [redacted], North Carolina. The store is open Mondays through Thursdays from 8:30 a.m. to 5:30 p.m., Fridays from 8:30 a.m. to 8:30 p.m., and Saturdays from 8:30 a.m. to 5:30 p.m. Staff prepare the floor and clean approximately one hour before and one hour after the store closes. The original analysis estimated that interior lighting fixtures remained on 3,588 hours per year. The total annual electricity use for the store is approximately 2,533,000 kWh, based on 2013 utility data.

Installed: This project involved replacing 10,000 60-watt halogen PAR38 lamps with 6,000 19-watt LED lamps. For every five halogen lamps, [redacted] installed three LED track lights. The installed LED lamp is a Philips 19PAR38/F36 2700 DIM AF and is listed on ENERGY STAR's certified LED list.

Goals and Objectives

Table 1 shows the projected savings goals identified in the project application.

Table 1. Project Goals

Application		Duke Energy			
Annual kWh Savings	Average kW Reduction	Projected Annual kWh Savings*	Claimed Annual kWh Savings	Claimed Coincident Peak kW Reduction	Claimed Non-CP kW Reduction
1,743,768	N/A	1,743,768	1,734,359	486.00	106.56

*Source: DSMore input spreadsheet.

For this M&V project, Cadmus sought to verify actual numbers for the following:

- Facility peak demand reduction (kW)
- Summer utility coincident peak demand reduction (kW)
- Annual energy savings (kWh)
- Annual realization ratios (kW and kWh)

Project Contacts

Table 2 lists the Duke Energy contact who granted Cadmus approval to plan and schedule the site visit for this M&V effort, along with the Cadmus contact and the customer contact.

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Table 2. Project Contacts

Organization	Contact	Contact Information
Duke Energy	Monica Redman, Senior DSM & Retail Programs Analyst	monica.redman@duke-energy.com
Cadmus	Christie Amero, Senior Analyst	office: 303-389-2509 christie.amero@cadmusgroup.com
Customer	redacted	

Site Location

The site location is listed in Table 3.

Table 3. Site Location

Address	ECM
redacted	1

M&V Option

To assess this site, Cadmus followed IPMVP Option A.

Implementation

Cadmus reached out to the site contact provided by Duke Energy to review the evaluation plan and to schedule the site visit. Christie Amero of Cadmus performed the site visit on June 22, 2016.

Field Survey

During the site visit, Cadmus met with the facility manager to review the lighting survey and to collect general operating information.

[Redacted] is one of the largest furniture retail stores in the country. The [redacted] location is composed of a campus of buildings containing showroom spaces, a food court, a warehouse, and offices. The main building is four floors and the showroom building is three floors. The main building and showrooms are open during the following periods:

- Mondays through Thursdays, from 8:30 a.m. to 5:30 p.m.
- Fridays, from 8:30 a.m. to 8:30 p.m.
- Saturdays, from 8:30 a.m. to 5:30 p.m.

The site closes only on Thanksgiving Day and Christmas Day.

The spaces where the new LEDs were installed are mainly showrooms for furniture products and do not have occupancy sensors, since dark areas may be an issue for sales. The lighting fixtures are typically turned on and off by facility staff approximately 30 minutes before the store opens and 30 minutes after the store closes. This is contrary to the original application, which stated that the lights are turned on an hour before the store opens and an hour after it closes.

The facility manager stated that the staff have seen a noticeable improvement in the quality of lighting for the retail spaces with the LED PAR38s, which is very important when selling furniture. The pre-retrofit 60-watt halogen lamps only lasted one or two years before they needed to be replaced.

Cooling for the facility is provided by water-cooled chillers of mixed age. There are electric perimeter heating coils, but they are only used a couple of days per year due to the high heat output from the lighting fixtures.

Field Data

ECM-1: Replace Halogen Lamps with LED Lamps

After completing the lighting survey, Cadmus performed a walkthrough of the facility to verify the installed lighting fixture types and to install light loggers. Figure 1 shows the installed PAR38 LEDs in one of the main showrooms. This design is typical throughout the facility. Figure 2 shows the make and model number of the installed PAR38 LED lamp.

Figure 1. Installed PAR38 LED Lamps in Showroom

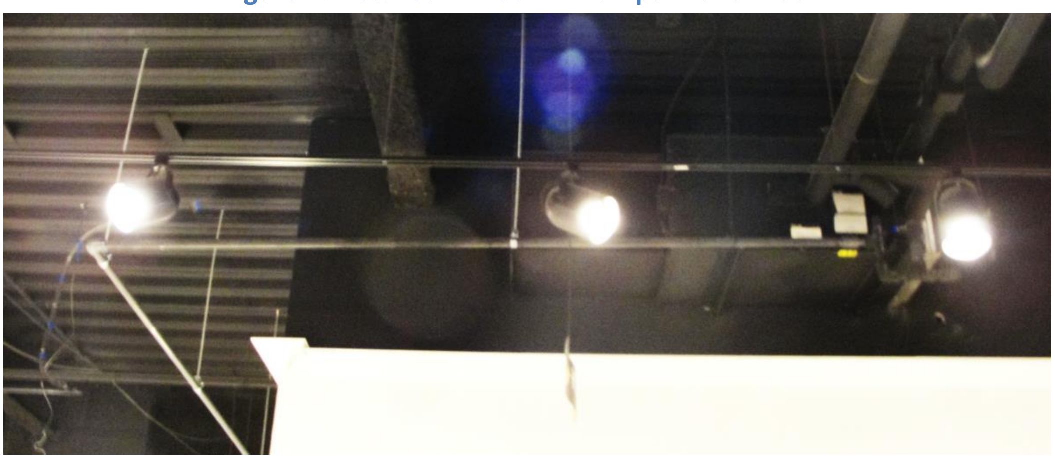

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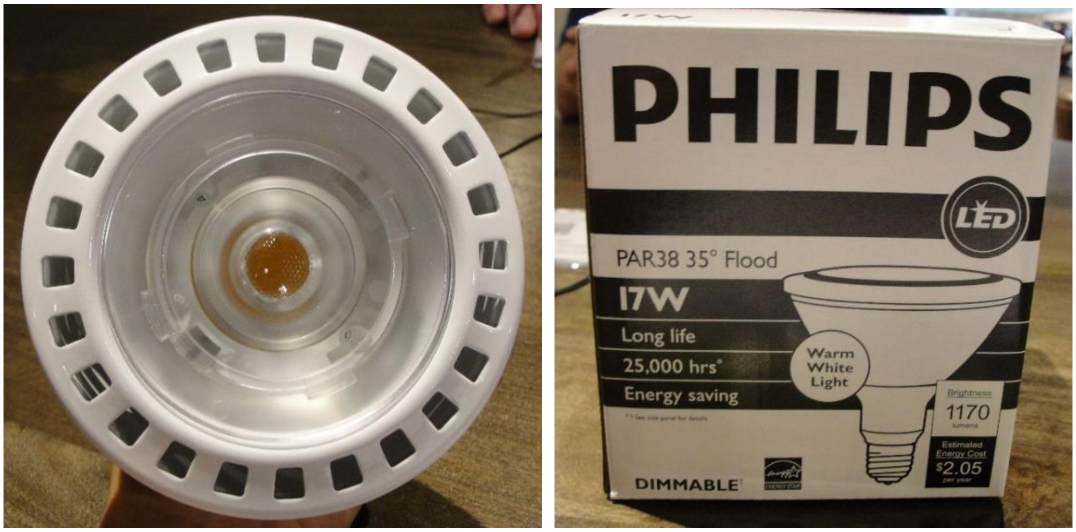
Figure 2. Make and Model of Installed LED Lamps



Cadmus installed six light loggers in a variety of spaces in the main building and showroom to collect fixture operating hours for a three-week period. Table 4 summarizes the locations of installed light loggers and monitored fixture type.

Table 4. Summary of Fixture Counts and Installed Light Loggers

#	Building	Location	Fixture Description	Light Logger Serial Number
1	Main	1st Floor, Section K06	PAR38 LED	10237836
2	Main	2nd Floor, Section M07	PAR38 LED	10168462
3	Main	3rd Floor, Section E10	PAR38 LED	10261680
4	Main	4th Floor, Section J10	PAR38 LED	10171991
5	Showroom	2nd Floor, Section C04	PAR38 LED	10326628
6	Showroom	1st Floor, Section D05	PAR38 LED	10268317

Data Analysis

ECM-1: Replace Halogen Lamps with LED Lamps

Cadmus used the survey and light logger data to verify demand and operating hours for the installed lighting fixtures. Table 5 summarizes light logger data.

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Table 5. Summary of Meter Data

#	Building	Total Hours Metered	Total Operating Hours	Percentage Operating	Average Time On	Average Time Off	Peak Coincidence Factor
1	Main	455.1	207.7	46%	7:08 a.m.	8:10 p.m.	100%
2	Main	455.1	210.0	46%	7:02 a.m.	7:27 p.m.	100%
3	Main	455.1	218.3	48%	6:58 a.m.	7:51 p.m.	100%
4	Main	455.3	158.5	35%	6:31 a.m.	8:56 p.m.	100%
5	Showroom	455.0	227.6	50%	6:40 a.m.	8:58 p.m.	100%
6	Showroom	455.2	226.0	50%	6:31 a.m.	8:42 p.m.	100%
Average		**455.1**	**208.0**	**46%**	**6:48 a.m.**	**8:21 p.m.**	**100%**

The six light loggers produced a mean projected runtime of 4,004 hours. During the three-week metering period, the site produced a mean peak coincidence factor of 100%.

The installed PAR38 LED lamp has an input of 17 watts, versus 19 watts as submitted in the original application. Cadmus could not verify the power usage of the pre-retrofit PAR38 halogen lamps, so we used their specific power of 60 watts for our calculations, based on a discussion with the site contact.

The energy savings and peak demand reduction without HVAC interactive effects are 1,993,949 kWh and 498.0 kW, respectively.

Cadmus also calculated energy savings and demand reductions with HVAC interactive effects, based on the heating and cooling system type collected on site. Cadmus used the waste heat factors listed in TechMarket Works' Process and Impact Evaluation of the Non-Residential Smart $aver® Prescriptive Program in the Carolina System: Lighting and Occupancy Sensors report submitted in April 2013. The energy waste heat factor for a big-box store near Greensboro, North Carolina with air conditioner cooling, electric heating, and no economizer is -0.149, and the demand factor is 0.218. The following equation is used to calculate savings with HVAC interactions:

$$kWh_{savings\ with\ HVAC} = kWh_{savings}\ x\ (1 + WHFe)$$

$$kW_{savings\ with\ HVAC} = kW_{savings}\ x\ (1 + WHFd)$$

Where:

WHFe = Waste heat factor for energy (= -0.149)

WHFd = Waste heat factor for demand (= 0.218)

Total evaluated energy savings were 1,696,851 kWh. The evaluated total summer coincident peak demand reduction (for the month of July, Monday through Friday from 4:00 p.m. to 5:00 p.m.) was 606.6 kW, and the average, or non-coincident, peak demand reduction was 193.7 kW.

Conclusion

While on the site, Cadmus found the equipment installed as expected. The overall energy savings realization rate was 98%, compared to Duke Energy claimed savings. The summer peak demand

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realization rate was calculated as 125%. The average (or non-coincident) peak demand reduction realization rate was 182%.

The greatest impact to the evaluated energy savings and demand reduction was that the original application did not account for HVAC interactive effects. The evaluated annual operating hours were also slightly higher than expected in the original application and the installed LED fixture wattage was slightly lower than expected.

Table 6 provides a comparison of the applicant, Duke Energy claimed, and Cadmus evaluated energy savings and demand reduction. Table 7 provides realization rates comparing energy savings and demand reductions claimed by Duke Energy to those calculated by Cadmus.

Table 6. Comparison of Applicant, Duke Energy Claimed, and Evaluation Energy Savings and Demand Reduction

Applicant		Duke Energy Claimed			Evaluation		
Annual kWh Savings	Average kW Reduction	Annual kWh Savings	Coincident Peak kW Reduction	Non-CP kW Reduction	Annual kWh Savings	Coincident Peak kW Reduction	Non-CP kW Reduction
1,743,768	N/A	1,734,359	486.00	106.56	1,696,851	606.6	193.7

Table 7. Energy Savings and Demand Reduction Realization Rates

Annual kWh Savings	Coincident Peak kW Reduction	Non-CP kW Reduction
98%	125%	182%

Application ID 13-1589525 Lighting Replacement: M&V Report

August 5, 2016

Duke Energy Carolinas
139 East Fourth Street
Cincinnati, OH 45201

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Introduction

This report addresses M&V activities for a lighting retrofit energy conservation measure (ECM) as part of the [redacted] Smart $aver custom incentive program application; specifically, the replacement of 934 lighting fixtures at one location in [redacted], NC.

ECM-1—Replace Metal Halide Fixtures with Fluorescent Fixtures

The plant replaced 869 400-Watt metal halide lighting fixtures with: 12, six-lamp T5-HO; 120, four-lamp T8; and 32, two-lamp, reduced wattage T8 fluorescent fixtures. The ECM included the removal of 589 fixtures.

ECM-2—Replace Fluorescent T12 Fixtures with T8 Fixtures

The plant replaced 65, two-lamp, 8' T12 fixtures with 40, four-lamp, reduced wattage T8 fixtures. The ECM included the removal of 25 fixtures.

Goals and Objectives

Table 1 summarizes the projected savings goals identified in the project application.

Table 1. Project Goals

ECM	Applicant		Duke Energy		
	Annual kWh Savings	Avg. kW Reduction	Claimed Annual kWh Savings*	Claimed Coincident Peak kW Reduction	Claimed Non-CP kW Reduction*
1	1,862,649	398	NA	306	NA
2	41,980	9	NA	4	NA
Total	**1,904,629**	**407**	**1,412,989**	**310.4**	**98.6**

* The program application documentation included claimed non-coincident peak demand and energy savings for the entire application and not for individual ECMs.

The M&V project sought to verify actual numbers for the following:

- Facility peak demand reduction (kW)
- Summer utility coincident peak demand reduction (kW)
- Annual energy savings (kWh)
- Annual realization rates (kWh and kW)

Project Contacts

The Duke Energy contact listed in Table 2 granted approval to plan and to schedule the site visit for the M&V effort.

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Table 2. Project Contacts

Organization	Contact	Contact Information
Duke Energy	Frankie Diersing	p: 513-287-4096 Frankie.diersing@duke-energy.com
Cadmus	Christie Amero	office: 303-389-2509 christie.amero@cadmusgroup.com
Customer	redacted	

Site Location

The location where this measure was installed is shown in Table 3.

Table 3. Project Location

Address	ECMs
redacted	1, 2

M&V Option

To assess this project, Cadmus utilized IPMVP Option A.

Implementation

Cadmus reached out to the site contact provided by Duke Energy to review the evaluation plan and to schedule the site visit. Christie Amero of Cadmus performed the site visit on January 7, 2016.

Field Lighting Survey

During the site visit, Cadmus met with the facility manager to review the attached lighting survey and to collect general operating information.

The facility manufactures foam pads for various types of furniture, with its busiest season late spring and early summer. Though heated by a gas-fired, hot water heating system, the warehouse does not employ space cooling. The offices are cooled by a standard DX cooling system (retrofits did not include fixtures in the offices).

The facility operates one shift Monday through Friday, from 6:00 am to 4:30 pm year round, even during the busy season. The site observes eight standard holidays per year. The spaces where new lighting fixtures were installed did not have occupancy sensors, but the site contact stated that lights were turned off at the end of each day.

Field Data

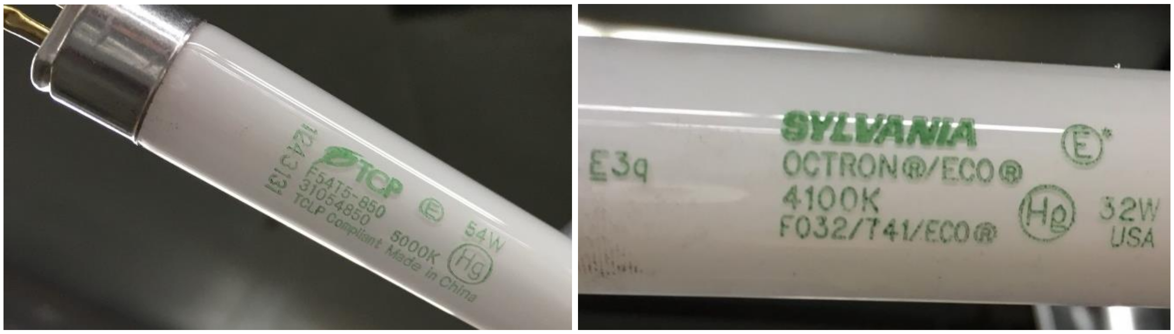
After completing the lighting survey, Cadmus performed a walkthrough of the facility to verify and count new lighting fixtures and to install light loggers. The facility included three main warehouse spaces: a center warehouse space with ~40' ceilings, and two spaces on either side with ~20' ceilings. Figure 1 shows lighting fixtures in the main warehouse space.

Figure 1. Main Warehouse Lighting Fixtures

Error! Reference source not found. shows a four-lamp, 2'x4', fluorescent fixture and a two-lamp, 4', luorescent fixture.

Figure 2. Installed Four-lamp 2'x4' and Two-lamp 4' Fluorescent Fixtures

Figure 3. Spare Lamps—54-Watt T5 (left) and 32-Watt T8 (right)



Cadmus installed light loggers throughout the facility to collect fixture operating hours for a two-week period. Table 4 summarizes fixture quantities and locations of installed light loggers.

Table 4. Summary of Fixture Counts and Installed Light Loggers

#	Location	Installed Fixtures Description	Light Loggers	
			Qty	Serial Number
1	Warehouse 1	4-lamp T8	1	10380561
2	Warehouse 1	2-lamp RW-T8	1	10380548
3	Large Warehouse - Row 1	6-lamp T5-HO	1	10380626
4	Large Warehouse - Row 2	6-lamp T5-HO	0	-
5	Large Warehouse - Row 3	6-lamp T5-HO	1	10380574
6	Large Warehouse - Row 4	6-lamp T5-HO	0	-
7	Large Warehouse - Row 5	6-lamp T5-HO	0	-
8	Large Warehouse - Row 6	6-lamp T5-HO	0	-
9	Large Warehouse - Row 7	6-lamp T5-HO	0	-
10	Large Warehouse - Row 8	6-lamp T5-HO	0	-
11	Large Warehouse - Row 9	6-lamp T5-HO	0	-
12	Large Warehouse - Row 10	6-lamp T5-HO	0	-
13	Large Warehouse - Row 11	6-lamp T5-HO	1	10380624
14	Large Warehouse - Row 12	6-lamp T5-HO	1	10380582
15	Warehouse 3	4-lamp T8	1	10380542
16	Warehouse 3	2-lamp T8	1	10380621
17	Shop	2-lamp T8	1	10380581
18	Shop	6-lamp T5HO	0	-
19	Small Room (Under Construction)	2-lamp 4' T8	0	-
Total	-	-	9	-

Figure 4, Figure 5, and Figure 6 show three locations where Cadmus installed light loggers.

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Figure 4. Light Logger #2 Location

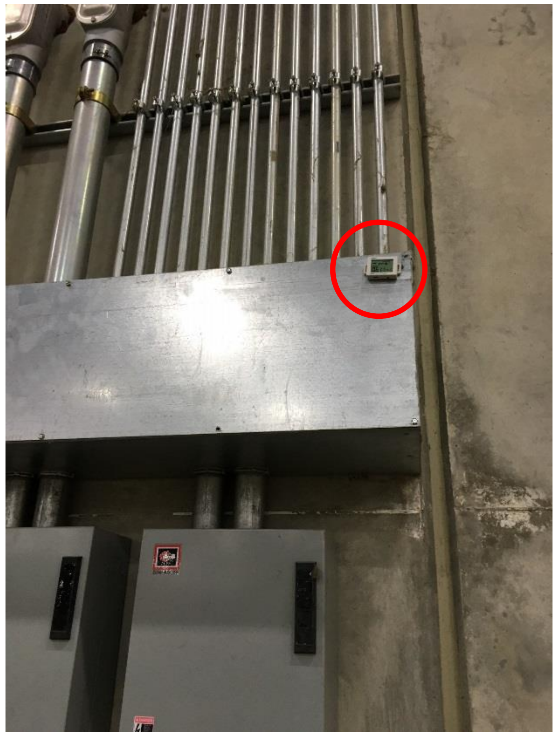

Figure 5. Light Logger #5 Location

Figure 6. Light Logger #7 Location

Data Analysis

Cadmus used the survey and light logger data to verify demand and operating hours for the installed lighting fixtures. The nine loggers produced a mean projected runtime of 2,306 hours. Though less than half of the hours assumed in the original analysis, this remains consistent with the operating schedule confirmed on site. During the two-week metering period, the site produced a mean coincidence factor of 18%. Table 5 summarizes light logger data, and Table 6 summarizes energy-savings calculations.

Table 5. Summary of Meter Data

S/N	Location	Hours Metered	Hours Operating	Percentage Operating	Projected Annual Operating Hours	Coincidence Factor
10380542	Warehouse 3	410	86	21%	1,840	0.13
10380548	Warehouse 1	410	126	31%	2,689	0.15
10380561	Warehouse 1	410	95	23%	2,026	0.1
10380574	Large Warehouse - Row 3	410	304	74%	6,505	0.71
10380581	Shop	410	6	1%	125	0
10380582	Large Warehouse - Row 12	410	44	11%	948	0.09
10380621	Warehouse 3	410	101	25%	2,168	0.13
10380624	Large Warehouse - Row 11	410	102	25%	2,191	0.1
10380626	Large Warehouse - Row 1	410	106	26	2,258	0.17

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Table 6. Savings Calculations

Annual Operating Hours	CF	Pre-Retrofit		Post-Retrofit		Energy Savings		
		Qty	kW	Qty	kW	Avg. kW Reduction	Peak Coincident kW Reduction	Annual kWh
2,306	0.18	869	0.5	128	0.4	306.1	55.1	705,807
				136	0.2			
				120	0.1			
				32	0.1			
		65	0.1	40	0.1	4.3	0.8	9,858
Total	**-**	**934**	**-**	**456**	**-**	**310.4**	**55.9**	**715,665**

Conclusion

Cadmus found the equipment installed as expected. The overall energy savings realization ratio was 51%, compared to Duke Energy claimed savings. The summer peak demand realization rate was calculated at 18%. The average (or noncoincident) peak demand reduction realization ratio was 315%.

Energy savings dropped because the initial analysis assumed 18 hours per day of operation, while the site contact claimed 10.5 hours; the meter data showed slightly less than that, on average. Cadmus suspects that the claimed coincident and non-coincident peak demand savings in Duke Energy's program tracking database were erroneously switched.

Table 7 provides a comparison of the applicant, Duke Energy claimed, and evaluation energy savings and demand reduction.

Table 8 provides realization rates compared to energy savings and demand reductions claimed by Duke Energy.

Table 7. Comparison of Applicant, Duke Energy Claimed, and Evaluation Energy Savings and Demand Reduction

ECM	Applicant		Duke Energy Claimed			Evaluation		
	Annual kWh Savings	Avg. kW Reduction	Annual kWh Savings	Coincident Peak kW Reduction	Non-CP kW Reduction	Annual kWh Savings	Coincident Peak kW Reduction	Non-CP kW Reduction
1	1,862,649	398	N/A	306	N/A	705,807	55.1	306.1
2	41,980	9	N/A	4	N/A	9,858	0.8	4.4
Total	**1,904,629**	**407**	**1,412,989**	**310.4**	**98.6**	**715,665**	**55.9**	**310.4**

Table 8. Energy Savings and Demand Reduction Realization Rates

ECM	Annual kWh Savings	Coincident Peak kW	Non-CP kW
1	N/A	18%	N/A
2	N/A	18%	N/A

Total	**51%**	**18%**	**315%**

Application ID 13-1360200
RTU Retrofit, Phase 1
M&V Report

Prepared for
Duke Energy South Carolina

January 2015, Version 4.0
(revised August 22, 2016)

Note: This project has been randomly selected from the list of applications for which incentive agreements have been authorized under Duke Energy's Smart $aver® Custom Incentive Program.

The M&V activities described here are undertaken by an independent third-party evaluator of the Smart $aver® Custom Incentive Program.

Findings and conclusions of these activities shall have absolutely no impact on the agreed upon incentive between Duke Energy and [redacted]

Submitted by:

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NORESCO, Inc.

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NORESCO
United Technologies

On August 22, 2016 the Duke Energy projected savings in this report were corrected by Cadmus to correspond to Duke Energy expected savings as found in the Duke Energy program tracking database.

Introduction

This report addresses M&V activities for the [redacted] custom program application. The application covers phase 1 of an RTU retrofit at one location in [redacted], South Carolina. The measure includes:

ECM-1 – DDC Controls

HVAC controls were added to (71) existing RTUs to allow for higher-level energy control strategies, including wintertime free cooling based on active enthalpy measurements. Synchronous (toothed belt) drives were also installed in place of V-belt drives to reduce supply fan energy and eliminate ongoing fan belt replacements. Existing RTUs were also modified to provide enthalpy-controlled economizer functions. In addition, (7) new high-efficiency RTUs were added to the building, although these were not part of the incented activities.

The installed RTUs constitute approximately 4,295 tons.

This project was completed in December 2013, so this M&V report covers post-retrofit monitoring and analysis only.

Goals and Objectives

The projected savings goals identified in the application were:

Facility	Proposed Annual kWh savings	Proposed kW Savings	Duke Expected Annual kWh savings	Duke Expected kW savings
redacted	6,299,169	0	6,299,172	11
Total	**6,299,169**	**0**	**6,299,172**	**11**

The objective of this M&V project was to verify the actual:

- Average pre/post load shapes by daytype for controlled equipment
- Facility peak demand (kW) savings
- Summer utility coincident peak demand (kW) savings
- Annual energy (kWh) savings

Project Contacts

Duke Energy M&V Coordinator	Frankie Diersing	p: 513-287-4096
NORESCO Engineer	Rob Slowinski	p: 303-459-7409 rslowinski@noresco.com
Customer Contact	redacted	

Site Locations/ECMs

Address
redacted

Data Products and Project Output

- Average pre/post load shapes by daytype for controlled equipment
- Facility peak demand (kW) savings
- Summer utility coincident peak demand (kW) savings
- Annual energy (kWh) savings
- kWh & kW Realization Rates

M&V Option

IPMVP Option A

M&V Implementation Schedule

- Conducted the post-retrofit survey after the customer had performed the controls and belt retrofit.
  - Data was collected during normal operating hours (with the Labor Day holiday coming within the middle of the monitoring period).
  - The post-retrofit HVAC schedules of the RTUs and fans were confirmed and duty cycles verified.
  - Spot-measurements were performed on selected controlled equipment.
  - Post-retrofit loggers were deployed to record temperature and power measurements on sampled equipment.
- The energy and demand savings of the retrofit measure were evaluated.

Field Survey Points

Pre – installation

- The pre-retrofit schedules, setpoints and other sequence of operation details for all controlled equipment (both RTUs and motors with new belts) were obtained. The pre-retrofit condition included no economizer operation, with interior cooling setpoints in the range of 68 to 70F.
- Nameplate data was obtained for all equipment.

Post – installation

- The new schedules, setpoints and other sequence of operation details were obtained and verified for all controlled equipment (both RTUs and motors with new belts).

Spot measurements

- V/A/kW/PF were collected for sampled RTUs and sampled motors with newly installed synchronous belts

  The sample included 15 of the 71 units, specifically the following RTUs:

  #4, 14, 17, 22, 25, 31, 36, 41, 49, 65, 71, 88, 101, 139, 141

Field Data Logging

- **ECM-1**

The following points were collected:

- Outdoor air temperature and relative humidity
- SAT, MAT, RAT, supply fan current for sampled RTUs

  The sample included the same 15 of the 71 units, specifically the following RTUs:

  #4, 14, 17, 22, 25, 31, 36, 41, 49, 65, 71, 88, 101, 139, 141

Trends and loggers were setup for 5-minute instantaneous readings and deployed for 3 weeks from August 15th to September 3rd, 2014.

Data Analysis

For the synchronous belt energy savings, the spot readings and trend data confirmed the power draw and operating schedule/duty cycle of the fan motors.

The Belt energy savings were calculated using the following equation:

$$Annual\ kWh\ savings_{Belt} = MonitoredMotorkW \times 8{,}760\frac{Hours}{Year} \times DutyCycle\ \times 0.0306$$

Where:

MonitoredMotorkW is the average non-zero fan motor kW from the trend data

DutyCycle is the percent of time that the fan motor is on

0.0306 is an assumed 3.06% energy savings improvement over standard V-belts, as verified by DOE research[1].

Belt demand savings was calculated using the following equation:

$$kW\ savings_{Belt} = MonitoredMotorkW \times CF \times 0.0306$$

Where:

CF is a coincidence factor, assumed to be 1.0, as all fans appear to be running at all times on weekdays

Economizer cooling energy savings was determined by confirming proper operation of the economizers by plotting mixed air and return air versus outside air, and observing the behavior as OA temperatures dropped. An economizer "lever" plot of MAT-RAT vs. OAT-RAT was also plotted, but due to some inconsistencies in the data, results were difficult to ascertain. Figures 1 and 2 show this relationship for RTUs 49 and 88. Economizing can be observed below about 80F on RTU49, as the slope of MAT is much greater than that of RAT. There is no observable economizing on RTU88.

[1] https://www1.eere.energy.gov/manufacturing/tech_assistance/pdfs/replace_vbelts_motor_systemts5.pdf

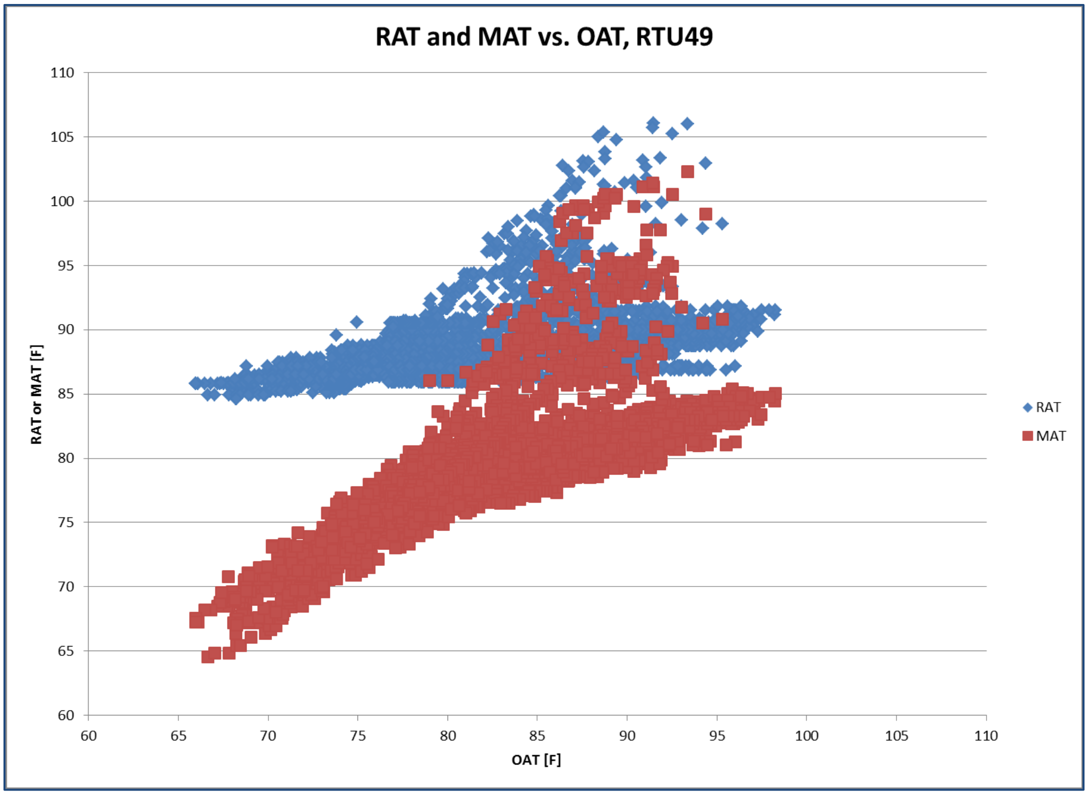

Figure 1: RTU49 Economizer Function.

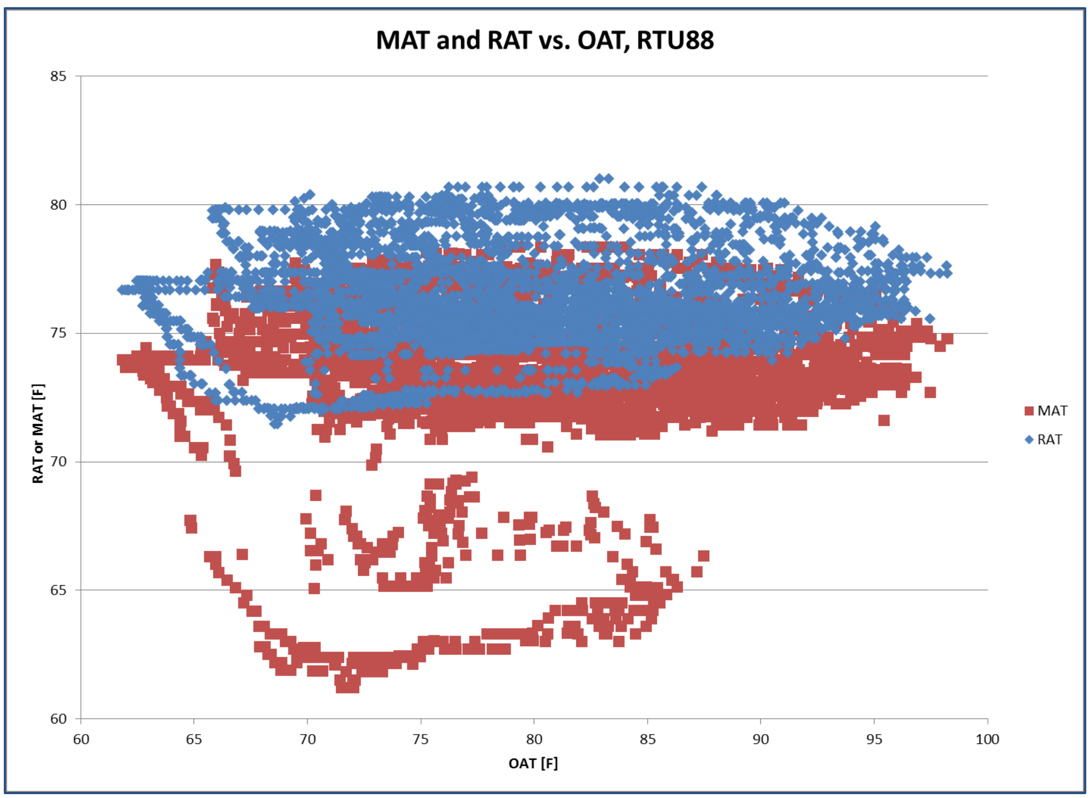

Figure 2: RTU88 Economizer Function.

It should be noted that economizing was not observed on the majority of sampled RTUs. However, because the savings from economizing occurs predominantly at lower outdoor air temperatures and because the 3-week logger data sample rarely included temperatures below 65F, it was assumed that economizing was in fact occurring at these lower temperatures. The site contact indicated that below 60F, all mechanical cooling was locked out. Time series plots—as seen in Figures 3 and 4—also showed brief periods of economizing for many of the RTUs.

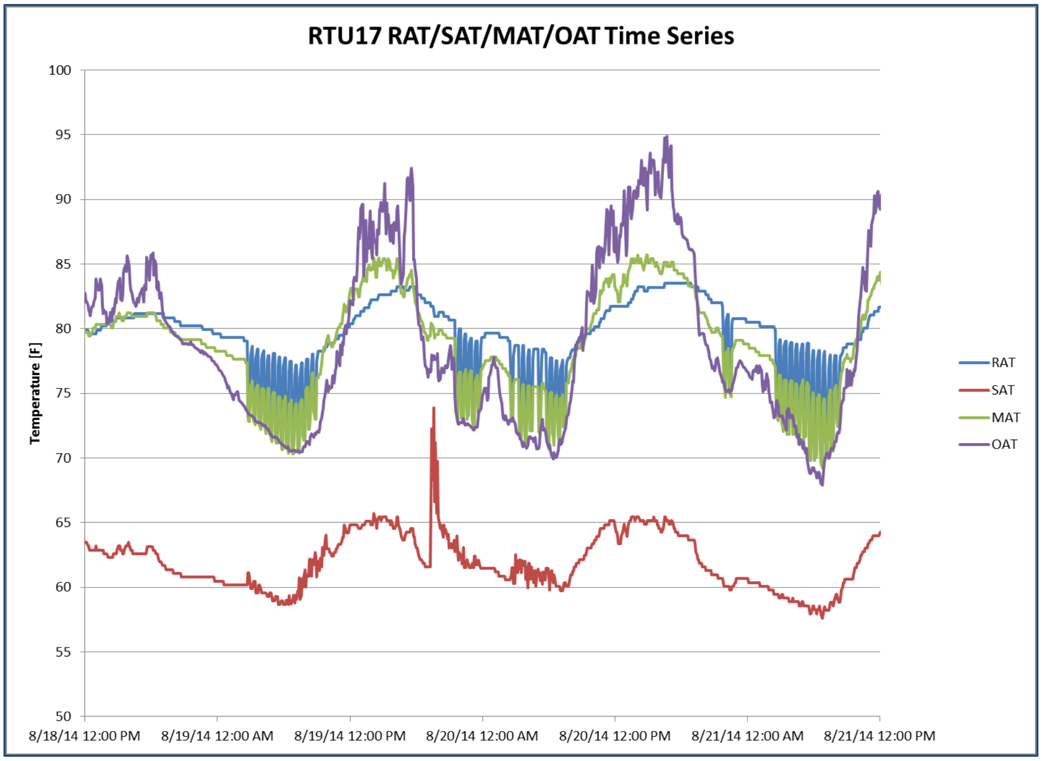

Figure 3: Time series plot of RTU 17 shows some economizing.

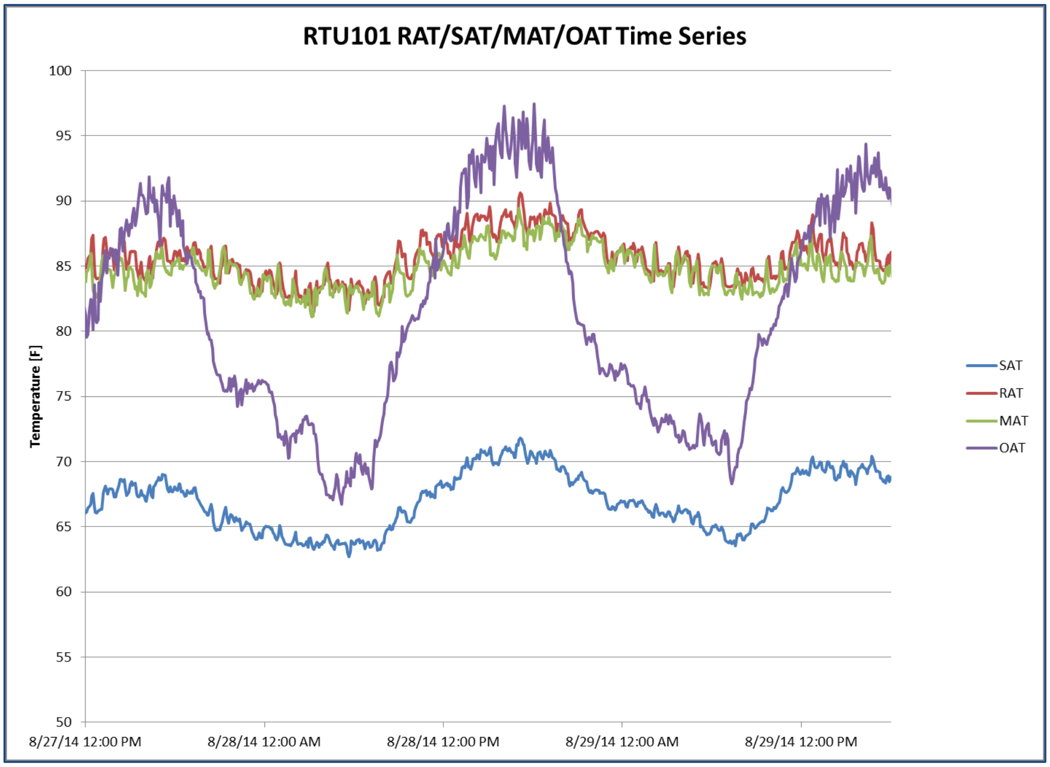

Figure 4: Time series plot of RTU 101 does not show evidence of economizing.

For each RTU, a regression of RAT vs. OAT was created, as seen in Figure 5.

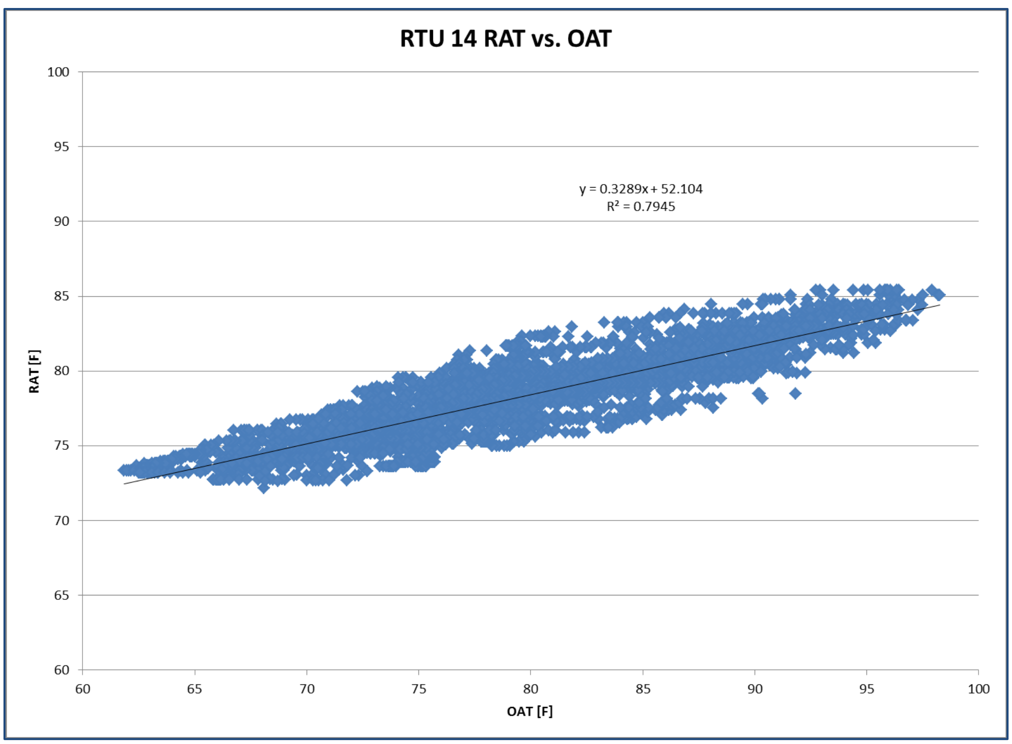

Figure 5: RTU14 RAT vs. OAT.

The RAT regressions were then used in the following equation to determine the cooling energy savings from economizing:

Economizer Energy Savings

Energy consumption from free cooling was determined using an hourly bin data analysis of outside air conditions and the following equations:

$$EnergySavings_{Econ} = \frac{4.5 \times CFM_{obs} \times (OAF_{ECM} - OAF_{base}) \times (h_{RA} - h_{OA})}{12{,}000 \times CoolingkWperTon}$$

$$CFM_{obs} = CFM_{rated} \times (\frac{P_{obs}}{P_{rated}})^{\frac{1}{2.7}}$$

$$OAF_{ECM} = (\frac{MAT - RAT}{OAT - RAT})$$

$$\mathrm{OAF_{base}} = 10\%$$

Where:

- *4.5* is a constant used in total heat equations, incorporating the heat density of dry air and a conversion from hours to minutes
- CFM_{obs} is the average RTU supply fan cubic feet per minute of airflow
- OAF_{ECM} is the outdoor air fraction according to a regression of RAT versus OAT from logged data
- OAF_{base} is the pre-retrofit fixed outdoor air fraction of 10%
- H_{RA} is the enthalpy of return air defined from the RAT versus OAT regression from logged data. This is calculated from the temperature and humidity of the return air
- H_{OA} is the enthalpy of outside air, calculated based on logged temperature and humidity of outside air
- *12,000* is a constant converting BTUs/hr to tons
- *CoolingkWperTon* is the cooling efficiency of the units
- CFM_{rated} is the rated airflow, in CFM, of each RTU supply fan
- P_{obs} is the observed kW from logger data
- P_{rated} is the rated kW of each supply fan
- *2.7* is a fan law constant for VFDs
- *MAT* is the assumed mixed air temperature, controlled to a minimum of 53F during conditions appropriate for economizing, given a discharge air setpoint of 55F and including fan heat

RTU fan schedules were not entirely consistent between the sampled units. Many units were scheduled off for a portion of the day on Saturdays, but some were scheduled for downtime on

Sundays. The length of the downtime was similar, but not completely consistent between the units and on some weekends the downtime appeared to be skipped altogether. In addition, for a couple of the monitored units, the fans appeared to be running at all times. For this reason, the average duty cycle was used to calculate annual energy savings, irrespective of whether a particular unit's downtime occurred on Saturdays, Sundays or not at all. Coincident peak (CP) demand savings was calculated at 3pm on July 17th. The (CP and non-CP) demand calculations for fan belts assumed a coincidence factor of 1.0, as all units appeared to be running at all times during weekdays.

Verification and Quality Control

1. Visually inspected logger data for consistent operation. Sorted by day type and removed invalid data. Looked for data out of range and data combinations that are physically impossible.
2. Verified that pre-retrofit and post retrofit equipment specifications and quantities were consistent with the application.
3. Verified electrical voltage of equipment circuits.

Recording and Data Exchange Format

1. Survey Form and Notes.
2. Building Automation System data files OR data logger files
3. Excel spreadsheets

Results Summary

The following table shows the results of the post-retrofit energy calculations, as compared to pre-retrofit estimates. Energy and demand savings listed in the table include the sum of both the belt retrofit measure and the economizer measure. Itemized belt savings accounted for 34,226 kWh and all of the demand savings (CP and non-CP) in the following energy savings totals:

	Energy Savings [kWh]	NCP Demand Savings [kW]	CP Demand Savings [kW]
Duke Expected	6,299,172	1,340	11
Verified	3,187,362	11.3	11.3
Realization Rate	51%	1%	105%

The verified energy savings results are low (as compared to the pre-retrofit estimates) due to the fact that many of the monitored units showed no signs of economizing during the logging period. It is true that outside air temperatures during the logging period tended to be somewhat high for economizing, but when economizing *was* observed, there seemed to be little observable evidence for *why* it was occurring. Perhaps logging temperatures and operation details during a period of more mild temperatures would show fuller economizer operation, but the data gathered during this project does not fully support that conclusion. There is an apparent clerical error in the reported NCP expected demand savings in the Duke Energy program tracking database as it is much higher than the coincident peak expected savings.

Application ID 13-1570850
HVAC
M&V Report

August 26, 2016

Duke Energy
139 East Fourth Street
Cincinnati, OH 45201

The Cadmus Group, Inc.
An Employee-Owned Company • www.cadmusgroup.com

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Table of Contents

Introduction

This report outlines Cadmus' measurement and verification (M&V) activities for one retrofit energy conservation measure (ECM) included as part of the [redacted], Smart $aver custom incentive program application—specifically for installing economizer controls and synchronous drives on 18 rooftop units (RTUs) at one location in [redacted], South Carolina. Energy savings were expected to result from reduced cooling energy use during shoulder seasons and improved motor efficiency. A description of the measure as submitted in the original application documentation is provided below.

ECM-1: Install Enthalpy Economizer Control and Synchronous Drives on Rooftop Units

Space conditioning for one of [redacted]'s gas turbine manufacturing facilities in South Carolina is provided by packaged RTUs. The 18 RTUs included in this retrofit project serve 117,250 square feet of the facility. The RTUs have direct expansion (DX) cooling coils, with a total cooling capacity of 695 tons and design supply airflow of 450,669 cfm. According to the original study, the facility is occupied 24 hours per day, seven days per week, year-round.

This project was Phase 2 of a two-phase project, where in Phase 1 the facility retrofitted 71 RTUs. The total annual electric energy use for the facility is approximately 158,400,000 kWh, based on 2012 and 2013 utility data.

Pre-Retrofit: In the pre-retrofit case, the 18 RTUs did not have economizers, and the DX cooling coils were required to operate whenever cooling was required. The RTU fans were all driven by standard V-belts, which depend on friction from a pulley; this generates heat and has the potential for slippage, versus tooth and sprocket engagement in a synchronous drive. V-belts also tend to elongate over time, causing belt creep.

Installed: The project involved retrofitting the 18 RTUs with enthalpy controlled economizers and synchronous drive motors. Economizer controls allow units to use outside air for space cooling when ambient conditions allow, reducing the load on DX cooling coils. Synchronous drives have been proven to be more efficient than V-belts because they reduce torque and speed loss. According to the Gates Corporation, switching from a V-belt to a synchronous belt drive system can improve motor efficiency by at least 5%[1].

In the original analysis, energy savings for the economizer controls were calculated using Hourly Analysis Program v4.51 analysis software. The simulation results with and without economizer control were compared. Energy savings for the synchronous drives were calculated using a Gates energy savings calculator. The original analysis assumed that all 18 RTUs had 15-hp fan motors with a full-load motor

[1] "Energy Savings from Synchronous Belts." Gates Corporation. 2014. http://designcenter.gates.com/wp-content/uploads/2015/05/Gates-Energy-Saving-from-Synchronous-Belt-Drives-White-Paper.pdf

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efficiency of 86%, operating 8,760 hours per year. The calculator used the Gates Corporation's estimated 5% savings for synchronous belts.

The total annual energy savings submitted in the original application were 1,909,006 kWh, or 1.2% of the total facility annual energy use.

Goals and Objectives

Table 1 shows the projected savings goals identified in the project application.

Table 1. Project Goals

Application		Duke Energy			
Annual kWh Savings	Average kW Reduction	Projected Annual kWh Savings*	Claimed Annual kWh Savings	Claimed Coincident Peak kW Reduction	Claimed Non-CP kW Reduction
1,895,093	N/A	1,909,006	1,909,006	2.45	122.70

* Source: DSMore input spreadsheet.

Cadmus' objective for this M&V project was to verify the following actual data:

- Facility peak demand reduction (kW)
- Summer utility coincident peak demand reduction (kW)
- Annual energy savings (kWh)
- Annual realization ratios (kW and kWh)

Project Contacts

Table 2 lists the Duke Energy contact who granted Cadmus approval to plan and schedule the site visit for this M&V effort, along with the Cadmus contact and the customer contact.

Table 2. Project Contacts

Organization	Contact	Contact Information
Duke Energy	Monica Redman, Senior DSM & Retail Programs Analyst	monica.redman@duke-energy.com
Cadmus	Christie Amero, Senior Analyst	office: 303-389-2509 christie.amero@cadmusgroup.com
Customer	redacted	

Site Location

The site location is listed in Table 3.

Table 3. Site Location

Address	ECM
redacted	1

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M&V Option

To assess this site, Cadmus followed IPMVP Option A.

Implementation

Cadmus reached out to the site contact provided by Duke Energy, seeking to review the evaluation plan and schedule the site visit. During the initial discussion with the site contact, Cadmus was informed that the energy management system (EMS) for the HVAC system currently trends energy use on all of the RTUs submitted in the application, and therefore additional on-site power metering would not be necessary. Christie Amero of Cadmus performed the site visit on June 21, 2016, to meet with the site contact and controls representative, review and set up available trend points, and physically verify the existing RTUs and installed synchronous belts.

Field Survey

During the site visit, Cadmus met with the site contact and controls representatives to review the EMS and collect general operating information. Nine of the 18 RTUs submitted in this application are located on the main manufacturing building and serve the power nozzle repair station (PRS), main distribution center (MDC), and bucket repair areas. The remaining nine RTUs are located on the combustion building.

According to the site contact, the site has increased the cooling load since the project was completed. There are more employees in the two buildings affected by the retrofits and the company added shifts during the weekends. There was also a significant amount of machine waste heat added to the spaces. Site contacts claimed that the interior space temperature at occupied level is maintained between 72°F and 74°F year round. The return air temperature is typically higher than the space temperature because the return air sensors are located in the ductwork in the ceilings (approximately 40’ high).

The site is currently running three shifts, Monday through Friday (24 hours per day) and two shifts on weekends (16 hours per day). The site typically shuts down for two full weeks per year for scheduled maintenance and observes typical federal holidays.

During the site visit, the controls representative relayed that the 18 RTUs had the capability to operate in economizer mode prior to the retrofit project. However, economizer mode had been disabled a few years before the retrofit because the original ductwork and controls dumped cold outside air directly down into the spaces, causing occupant discomfort.

For the retrofit project, the facility changed the space thermostats, improved airflow to the spaces by adding diffusers, and improved economizer change-over controls. The mixed air temperature is now maintained at a minimum of 55°F during the winter months to prevent cold air from being dumped into the spaces.

According to the facility contact, economizer operation is based on outside air dry bulb temperature (not enthalpy, as expected in the original application) and is enabled when the difference between the

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return air temperature and outside air temperature is greater than 5°F. For example, if the return air temperature is 80°F and the outside air temperature is 74°F, the system will go into economizer mode.

Field Data

ECM-1: Install Enthalpy Economizer Control and Synchronous Drives on Rooftop Units

Cadmus collected the trend data shown in Table 4 for all installed equipment included in the application. All 18 RTUs are Trane constant volume packaged units with an average cooling capacity of approximately 36 tons. During the site inspection, Cadmus found that two of the RTU fan motors had V-belt drives (RTU-165 and RTU-166). According to the site contact, synchronous drives were installed in these RTUs during the project, but had to be replaced with V-belts. The RTUs all have constant speed fans (no variable frequency drives), and frequent stopping and starting causes wear and tear on the synchronous belts. The synchronous belts on a few of the remaining retrofitted RTUs were missing some teeth due to this issue.

Table 4. Installed Equipment Nameplate Data

Building	Equipment ID	Make	Model #	Cooling Capacity, tons	Fan hp	Belt Type
Combustion	RTU-132	Trane	SFHCC404HTS6	40	15	Synchronous
	RTU-133	Trane	SFHCC404HTS6	40	15	Synchronous
	RTU-134	Trane	SFHCC404HTS6	40	15	Synchronous
	RTU-135	Trane	SFHCC404HTS6	40	15	Synchronous
	RTU-136	Trane	SFHCC404HTS6	40	15	Synchronous
	RTU-138	Trane	SFHCC404HTS6	40	15	Synchronous
	RTU-139	Trane	SFHCC404HTS6	40	15	Synchronous
	RTU-140	Trane	SFHCC404HTS6	40	15	Synchronous
	RTU-141	Trane	SFHCC404HTS6	40	15	Synchronous
MDC/PRS	RTU-165	Trane	50DL44600AA	40	15	V-Belt
	RTU-166	Trane	YCD480A4LF2A3	40	15	V-Belt
	RTU-601	Trane	50DF034620PA	30	15	Synchronous
	RTU-608	Trane	50DF034620PA	30	15	Synchronous
	RTU-609	Trane	50DF034600PA	30	15	Synchronous
Bucket Repair	RTU-167	Trane	SFHFF304HA58	30	15	Synchronous
	RTU-168	Trane	SFHFF304HA58	30	15	Synchronous
	RTU-169	Trane	SFHFF304HA58	30	15	Synchronous
	RTU-170	Trane	SFHFF304HA58	30	15	Synchronous

Figure 1 shows the RTU layout for the main building and combustion building. The RTUs included in this retrofit project are circled in yellow. As stated above, a majority of the RTUs serving the manufacturing area of the main building were retrofitted as part of Phase 1.

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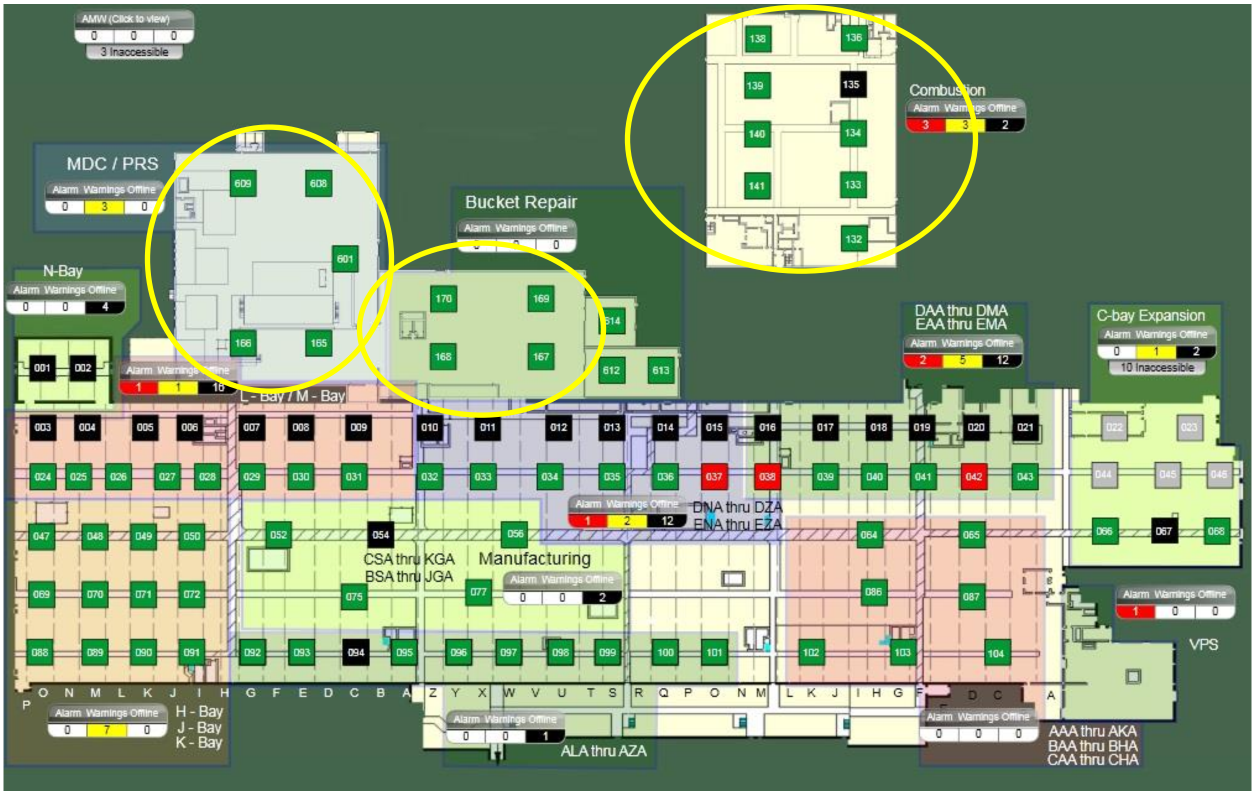
Due to the sensitive nature of the products at the site, Cadmus was not able to bring a laptop or camera to take photographs of the installed equipment or controls.

Figure 1. Main and Combustion Building RTU Layout



Cadmus also collected five weeks of energy use (kWh) trend data from the site, for most of the RTUs submitted in the application. The facility provided the cooling command, outside air damper positon, zone temperature, and return and discharge air temperature for the combustion building RTUs only. Table 5 summarizes the points we collected from the system. The site had not saved data from the earlier shoulder season so Cadmus was only able to obtain and analyze July data. This limited the amount of economizing that Cadmus could observe. As explained later we did see some inconsistent controls behavior. Given the lack of data from prime economizing periods we based our analysis on the site successfully economizing during low outside air temperatures.

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Table 5. Provided Trend Points for RTUs

Building	Number of RTUs	Trend Point	Interval	Duration
Combustion (9 RTUs)	9	Energy Use, kWh	1 hour	5 weeks
	7	Zone Temperature, °F	30 minutes	5 weeks
	6	Discharge Air Temperature, °F	30 minutes	5 weeks
	6	Return Air Temperature, °F	30 minutes	5 weeks
	7	Cooling Command, %	30 minutes	5 weeks
	8	Outside Air Damper, %	30 minutes	5 weeks
MDC/PRS* (5 RTUs)	4	Energy Use, kWh	1 hour	5 weeks
	-	Zone Temperature, °F	-	-
	-	Discharge Air Temperature, °F	-	-
	-	Return Air Temperature, °F	-	-
	-	Cooling Command, %	-	-
	-	Outside Air Damper, %	-	-
Bucket Repair (4 RTUs)	4	Energy Use, kWh	1 hour	5 weeks
	4	Zone Temperature, °F	10 minutes	5 weeks
	-	Discharge Air Temperature, °F	-	-
	-	Return Air Temperature, °F	-	-
	-	Cooling Command, %	-	-
	-	Outside Air Damper, %	-	-

* Trend data for RTU-601 on the MDC/PRS building was not provided.

Data Analysis

ECM-1: Install Enthalpy Economizer Control and Synchronous Drives on Rooftop Units

Cadmus used the trend data for the installed equipment to verify the demand and operating hours of the RTUs. Table 6 summarizes the average operating demand for each of the RTUs based on the trend data collected.

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Table 6. Summary of Trend Data

Building	RTU ID	Average Operating Demand, kW
Combustion	RTU-132	30.5
	RTU-133	20.8
	RTU-134	8.4
	RTU-135	46.5
	RTU-136	28.0
	RTU-138	27.1
	RTU-139	29.9
	RTU-140	43.00
	RTU-141	27.02
MDC/PRS	RTU-165	41.6
	RTU-166	45.1
	RTU-601*	N/A
	RTU-608	44.6
	RTU-609	48.0
Bucket Repair	RTU-167	23.7
	RTU-168	26.0
	RTU-169	17.3
	RTU-170	31.7

* Data for RTU-601 was not provided. Cadmus assumed the demand for RTU-601 by taking the average demand of RTU-608 and RTU-609.

As a preliminary estimate of the potential energy savings, Cadmus extrapolated the average trended RTU demand to typical annual operation. We calculated fan motor demand using the manufacturers' nameplate horsepower rating with assumed motor load factor of 85.0% and motor efficiency of 86.0%. We estimated the percentage of fan motor demand versus compressor demand by divided the calculated fan demand by the total average trended demand. Cadmus used the average percentage of fan demand for all 18 RTUs (36%) to calculate the total annual fan energy use using the following equation.

$$\text{Total Annual Fan Energy Use, kWh} = \text{Total Trended Average RTU Demand, kW} * \\ \text{\% Fan Demand} * 8{,}760 \text{ hours} \qquad [1]$$

The estimated total annual fan energy use was 1,834,049 kWh. We calculated the total estimated pre-retrofit cooling energy use assuming cooling was required ten months of the year.

$$\text{Total Annual Cooling Energy Use, kWh} = \text{Total Trended Average RTU Demand, kW} * \\ (1 - \text{\% Fan Demand}) * 7{,}300 \text{ hours} \qquad [2]$$

The estimated total annual pre-retrofit cooling energy use was 2,745,655 kWh, and total overall pre-retrofit RTU energy use was 4,579,704 kWh. The total cooling-only energy savings submitted in the original application was 1,797,406 kWh, which is 65% of the estimated annual pre-retrofit cooling

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energy use. Based on this comparison, Cadmus estimated that the cooling energy savings submitted in the original application were too high relative to the pre-retrofit energy use. Table 7 presents the calculations performed for this preliminary estimate.

Table 7. Preliminary Estimate of Pre-Retrofit Energy Use Based on Trended Demand Data

RTU ID	Trended Average Demand, kW	Estimated Fan Demand, kW	Percent Fan Demand	Estimated Annual Pre-Retrofit Energy Use, kWh		
				Fan	Cooling (10 months)	Total
132	30.5	11.1	36%	95,627	143,159	238,786
133	20.8	11.1	53%	65,122	97,491	162,613
134	8.4	11.1	-	26,235	39,275	65,510
135	46.5	11.1	24%	145,556	217,904	363,460
136	28.0	11.1	40%	87,578	131,108	218,686
138	27.1	11.1	41%	85,029	127,293	212,322
139	29.9	11.1	37%	93,673	140,233	233,906
140	43.00	11.1	26%	134,707	201,662	336,368
141	27.02	11.1	41%	84,629	126,694	211,324
165	41.6	11.1	27%	130,280	195,034	325,314
166	45.1	11.1	25%	141,383	211,657	353,040
601*	N/A	11.1	47%	74,390	111,365	185,754
608	44.6	11.1	43%	81,339	121,769	203,108
609	48.0	11.1	64%	54,311	81,305	135,616
167	23.7	11.1	35%	99,165	148,455	247,620
168	26.0	11.1	24%	145,008	217,084	362,092
169	17.3	11.1	25%	139,764	209,233	348,997
170	31.7	11.1	23%	150,252	224,935	375,187
Total	**585.5**	**199.1**	**36%**	**1,834,049**	**2,745,655**	**4,579,704**
Original Application Cooling Energy Savings, kWh						**1,797,406**
Original Application Cooling Energy Savings Compared to Estimated Cooling Energy Use						**65%**

* Data for RTU-601 was not provided. Cadmus assumed the demand for RTU-601 by taking the average demand of RTU-608 and RTU-609.

Our next step in the M&V process was to create an 8,760 hour model with typical meteorological year (TMY) data for [redacted], South Carolina. Since coincident outside air conditions were not available from the site's trend system, we collected coincident weather data from the [redacted] airport weather station. The minimum outside air dry bulb temperature was 68°F during the trend data collection period, which is high for standard economizing. Ideally, we would collect data during a shoulder season to observe the units in typical economizer operation, however the site did not retain data from the earlier shoulder season.

We did not observe economizer operation in a majority of the RTUs, and the units that did economize appeared to do so sporadically. Figure 2 and Figure 3 show plots of the outside air damper position (percent open) and cooling command (on/off) with outside air dry bulb temperature for RTU-136, which

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is the only unit that consistently operated in economizer mode. In Figure 2, the damper appears to open only when the outside air temperature is below approximately 72°F, but Figure 3 shows the damper opening at 94°F outside air dry bulb temperature on July 11th. This likely increased cooling loads and energy use. We suggest that Duke Energy contact the site about this observation.

Figure 4 shows a similar plot for RTU-134, which did not economizer at all during the trend period, but serves an adjacent building area to RTU-136.

Figure 2. RTU-136 Outside Air Damper Position and Cooling Command (Primary Y-Axis) and Outside Air Dry Bulb Temperature (Secondary Y-Axis) – July 4th through 9th

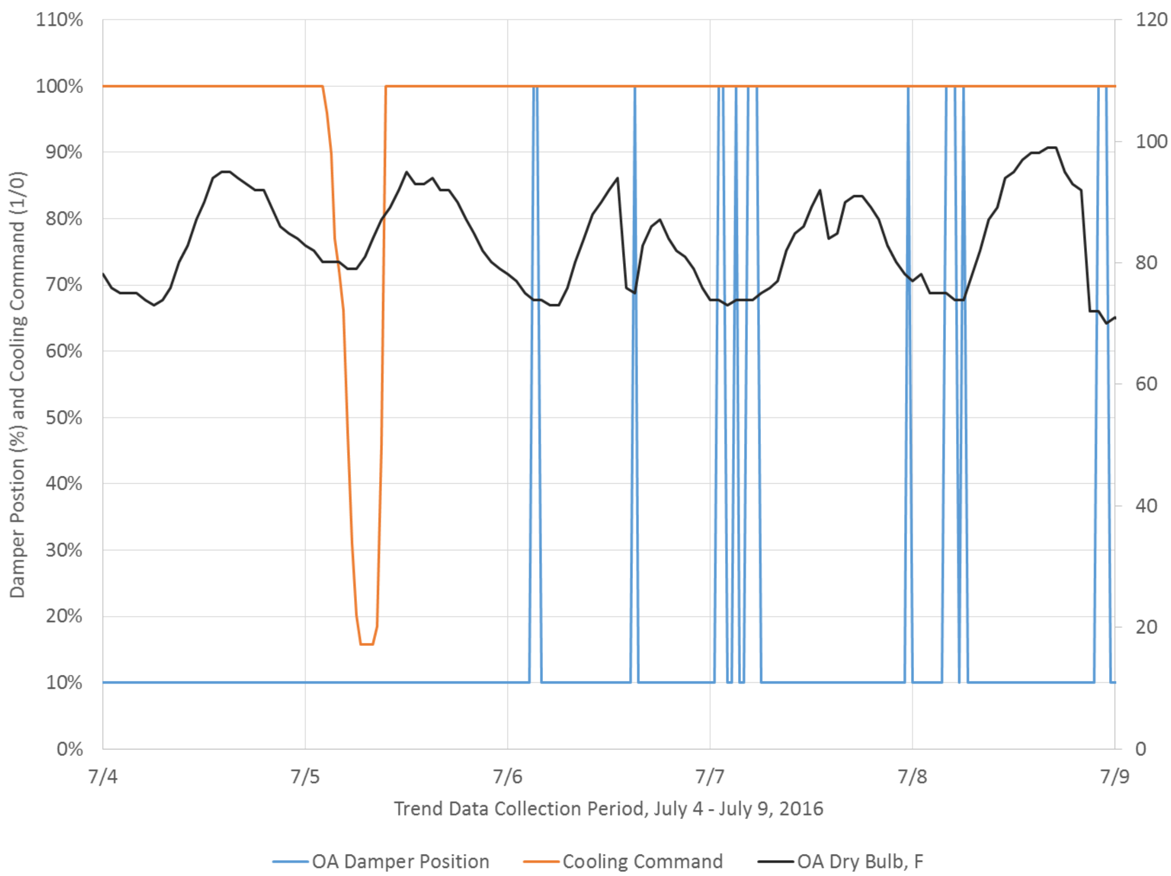

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Figure 3. RTU-136 Outside Air Damper Position and Cooling Command (Primary Y-Axis) and Outside Air Dry Bulb Temperature (Secondary Y-Axis) – July 9th through 14th

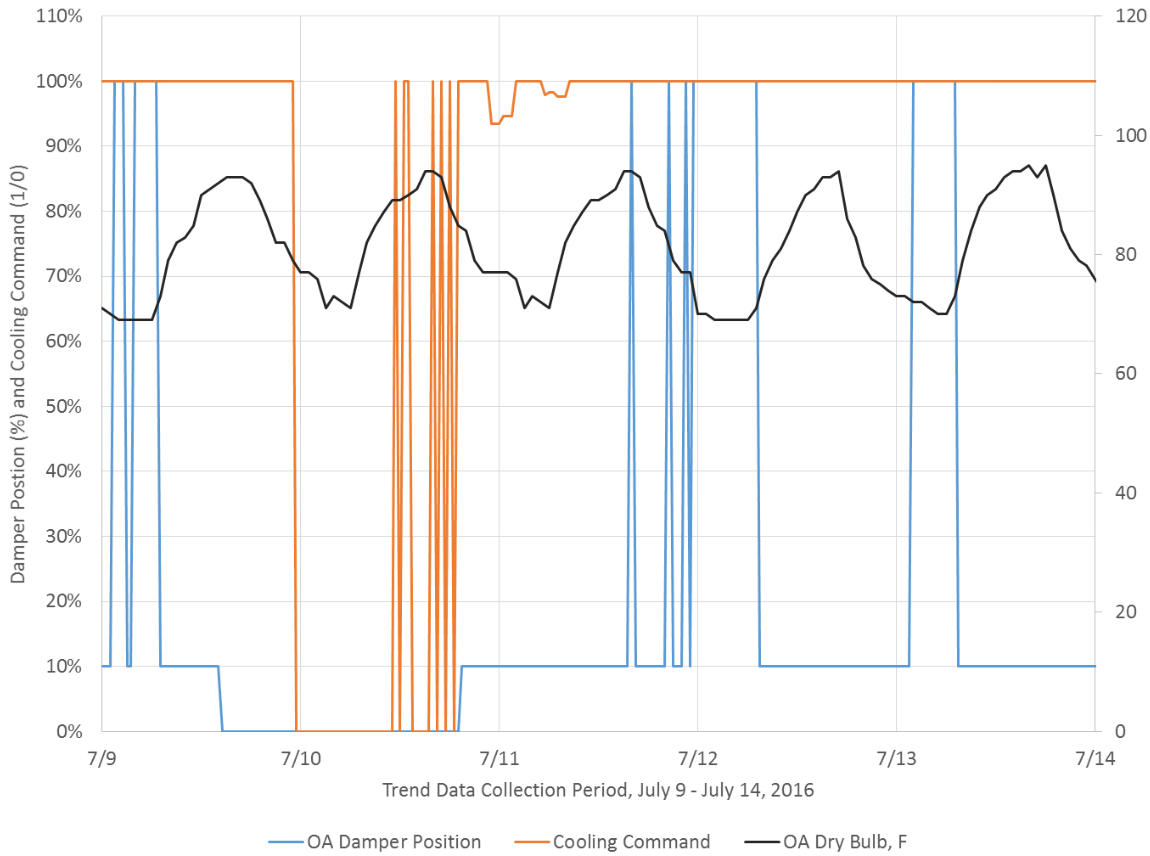

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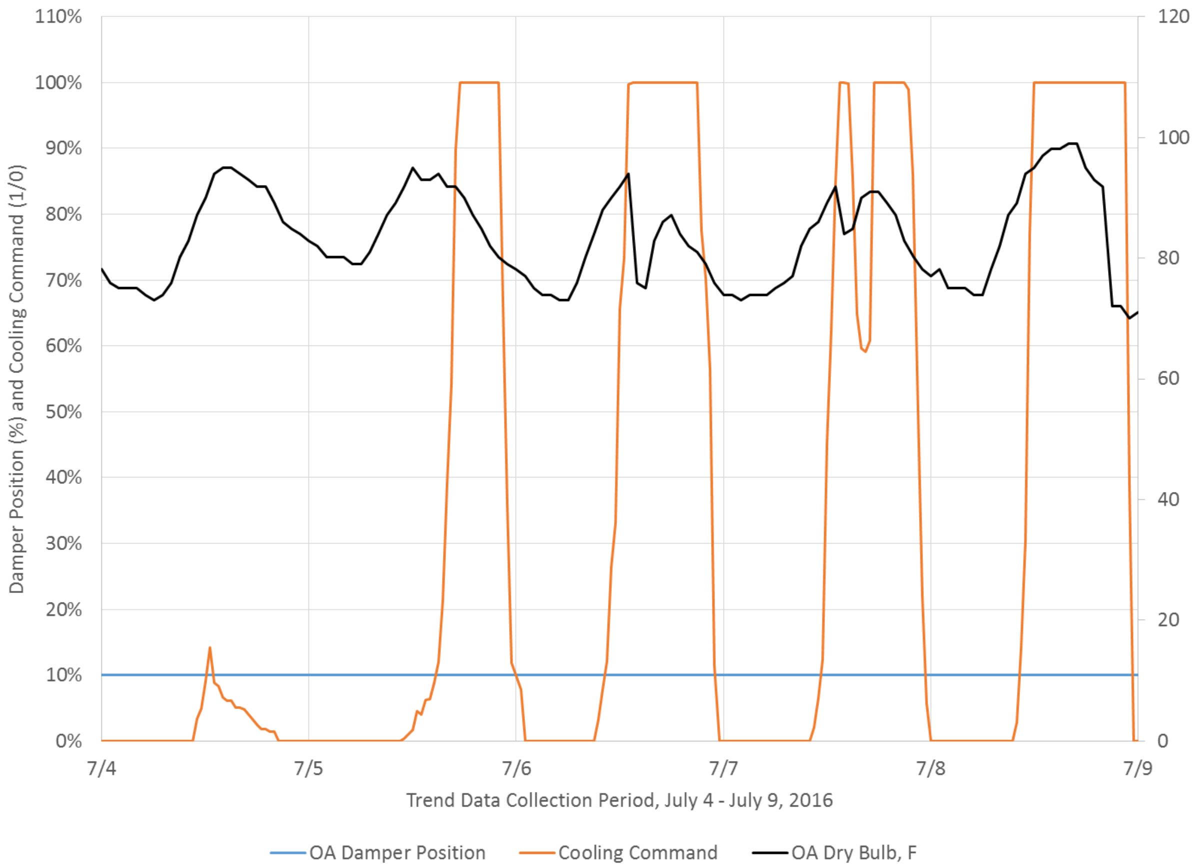
Figure 4. RTU-134 Outside Air Damper Position and Cooling Command (Primary Y-Axis) and Outside Air Dry Bulb Temperature (Secondary Y-Axis) – July 4th through 9th



We could not confirm economizer operation at mild outside air conditions because we did not have trend data for standard economizer conditions. We evaluated the measure based on the site contact's description of economizer operation and the return and discharge air temperatures provided. Cadmus averaged the trended discharge (DAT) and return air temperatures (RAT) provided for six of the 18 RTUs. Figure 5 shows the plot of average RAT versus coincident outside air dry bulb temperature and Figure 6 shows the plot of average DAT versus outside air dry bulb temperature. We used the linear trend fits from these curves to calculate the DAT and RAT for the pre-retrofit and installed system energy use calculations in the hourly model.

Figure 5. Average RAT vs. Outside Air Dry Bulb Temperature

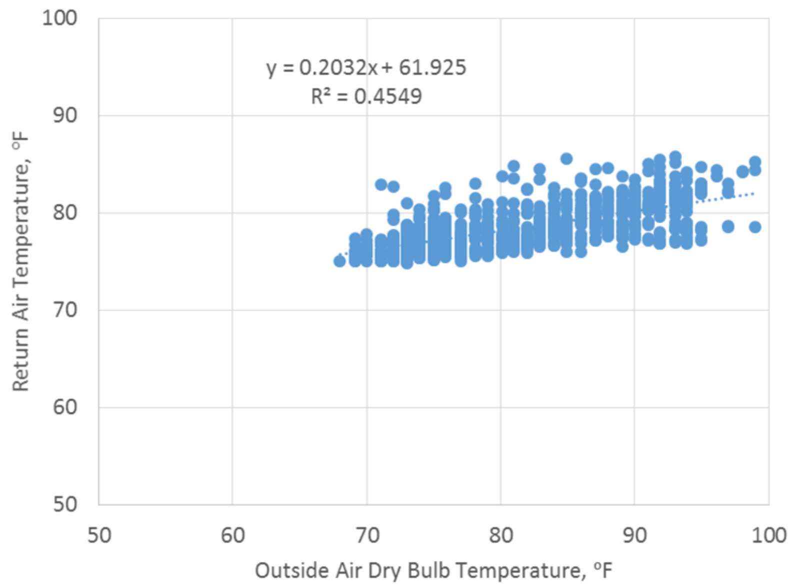
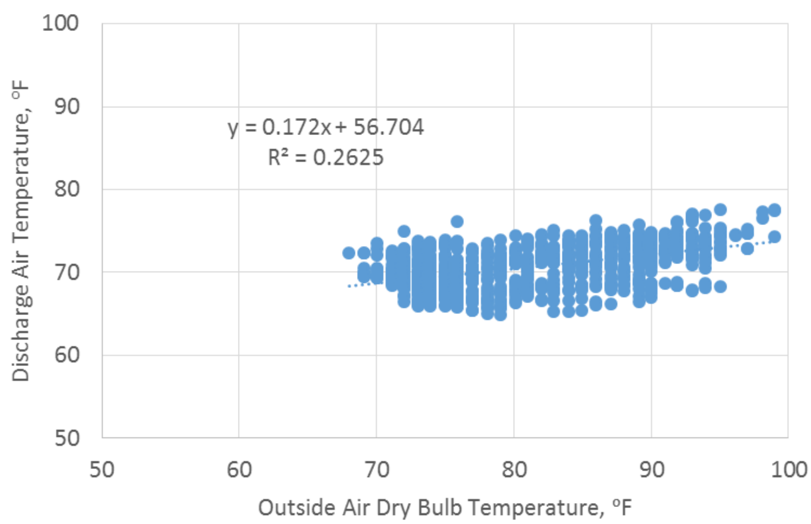


Figure 6. Average DAT vs. Outside Air Dry Bulb Temperature



In the pre-retrofit case, we assumed the minimum outside air flow rate was 10%. We calculated the pre-retrofit mixed air temperature (MAT, temperature of air before the cooling coil) using the following equation:

$$MAT = (\text{Outside Air Dry Bulb, °F} - \text{RAT, °F}) * \text{Percent of outside Air, \%} + \text{RAT, °F} \quad [3]$$

In the pre-retrofit case, the DX cooling coils would have been required to operate whenever the MAT was greater than the DAT, but we applied a cooling cutoff at 40°F outside air temperature, since the site would likely shut lockout the cooling coils at low temperatures to prevent freezing. The total design supply airflow rate for the 18 RTUs is 450,669 cfm based on original application. Cadmus assumed the average supply airflow is 90% of design, or 405,602 cfm. We then calculated the cooling load using the following equation:

Cooling Load, tons = Supply Airflow, cfm * 1.08 * (MAT, °F – DAT, °F) / 12,000 Btu/hr/ton [4]

We used the RTU compressor performance listed on manufacturer's specification sheets to calculate the pre-retrofit RTU cooling demand. The total fan motor demand was calculated using the manufacturers' nameplate horsepower ratings with assumed motor load factor of 85.0% and motor efficiency of 86.0%. We also assumed an average annual fan cycling of 90%. The evaluated pre-retrofit annual energy use was 3,406,597 kWh. The coincident peak demand was 490.9 kW, and average annual demand was 388.9 kW.

The installed case economizer outside air dry bulb change-over temperature was estimated using psychrometric equations. The average annual return air temperature based on the hourly model is 76.0°F and the interior relative humidity is maintained at approximately 50%, according to the site contact. At these conditions, the enthalpy is 28.7 Btu/lb. Cadmus assumed economizer operation would be beneficial when the outside air enthalpy was 1.0 Btu/lb. below the return air conditions. At outside air conditions of 27.7 Btu/lb. and 100% relative humidity, the dry bulb is 61.9°F. Therefore, Cadmus assumed economizer mode would be enabled when the outside air dry bulb was less than 61.9°F. The minimum MAT is 55°F, based on information from the site contact, so Cadmus calculated the installed system outside air percentage using equation [3] above. We then calculated the installed system cooling load and demand using the same method as the pre-retrofit case.

Cadmus used the U.S. Department of Energy's 3%[2] motor energy savings estimate for synchronous belts for the units that currently have synchronous belts. The evaluated installed annual energy use is 2,594,428 kWh. The coincident peak demand is 486.0 kW, and the average annual demand is 296.2 kW.

The total evaluated energy savings for the 18 RTUs in Phase 2 were 812,169 kWh. The evaluated total summer coincident peak demand reduction (for the month of July, Monday through Friday from 4:00 p.m. to 5:00 p.m.) was 4.87 kW, and the average, or non-coincident, peak demand reduction was 92.71 kW. Figure 7 shows a comparison of the pre-retrofit versus installed evaluated total system demand.

[2] "Replace V-Belts with Notched or Synchronous Belt Drive." U.S. Department of Energy. November 2012. https://www1.eere.energy.gov/manufacturing/tech_assistance/pdfs/replace_vbelts_motor_systemts5.pdf

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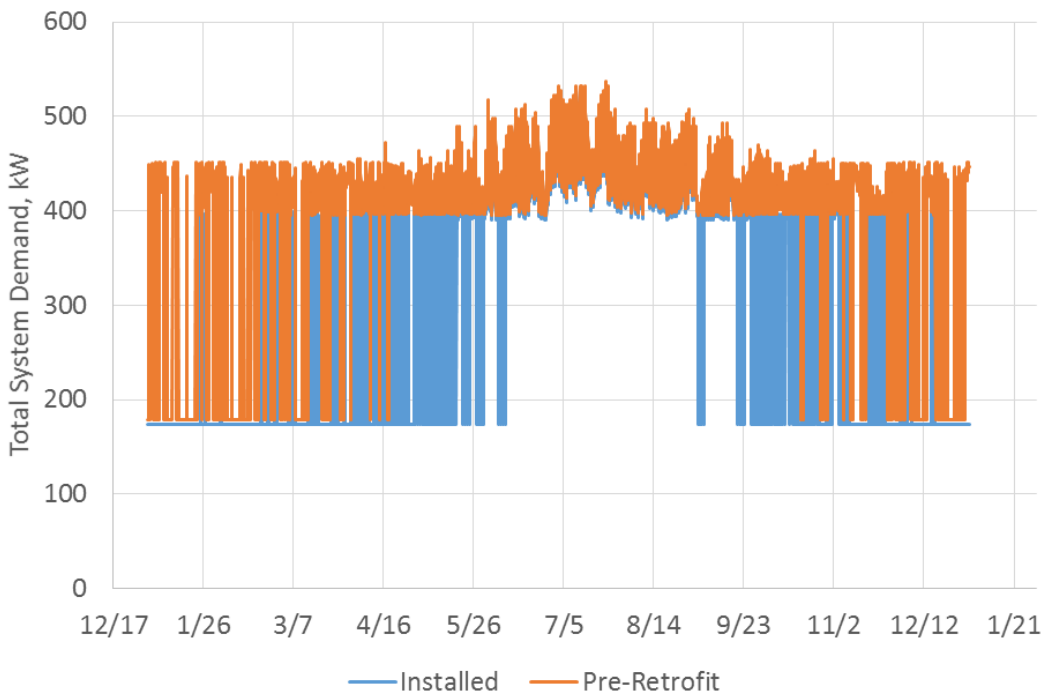
Figure 7. Comparison of Evaluated Pre-Retrofit versus Installed Total System Demand



Conclusion

Cadmus found the equipment and controls installed as expected, with minor exceptions of the motor belts for two of the RTUs. While the economizer controls were confirmed to be installed, there may be issues with the control strategies since most of the RTUs did not operate in economizer mode as described by the site contacts during the trend data collection period, and three of the nine RTUs we have data for appeared to open their dampers fully during warm periods. The outside air dry bulb temperatures during the trend period were high for economizing, but when the outside air damper positions were observed to be 100% open in a few of the RTUs, there seemed to be little correlation for why it was occurring in some units and not others.

Since the site did not provide supply or return temperature or damper position trends for all of the RTUs, we could not meter internal loads, and the trend data was provided during the month of July, it is difficult for Cadmus to conclude whether the economizer controls are functional at all. The evaluated savings assume the RTUs economize at low outside air conditions, but Cadmus recommends that Duke Energy follow up with the site to discuss these issues and potentially collect another round of trend data during cooler outside air conditions.

The original application also claimed the fan motor energy savings from synchronous drives to be 5% over V-belt drives, but the U.S. D.O.E. supports energy savings of 3%.

The overall energy savings realization rate was 42.5%, compared to the Duke Energy claimed savings. The summer peak demand realization rate was calculated as 198.5%. The average (or non-coincident)

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peak demand reduction realization rate was 75.6%. The realization rate is low because it appears the original application claimed cooling savings of 65% of the estimated pre-retrofit RTU cooling energy. This is a large savings value considering that economizing will typically only take place below 62°F. The original application savings may have arose from an estimated cooling load that was higher than actual.

Table 8 provides a comparison of the applicant, Duke Energy claimed, and Cadmus evaluated energy savings and demand reduction. Table 9 provides realization rates comparing the energy savings and demand reductions claimed by Duke Energy to those calculated by Cadmus.

Table 8. Comparison of Applicant, Duke Energy Claimed, and Evaluation Energy Savings and Demand Reduction

Applicant		Duke Energy Claimed			Evaluation		
Annual kWh Savings	Average kW Reduction	Annual kWh Savings	Coincident Peak kW Reduction	Non-CP kW Reduction	Annual kWh Savings	Coincident Peak kW Reduction	Non-CP kW Reduction
1,895,093	N/A	1,909,006	2.45	122.70	812,169	4.87	92.71

Table 9. Energy Savings and Demand Reduction Realization Rates

Annual kWh Savings	Coincident Peak kW Reduction	Non-CP kW Reduction
42.5%	198.5%	75.6%

Application ID 14-1651242 Lighting Replacement: M&V Report

August 5, 2016

Duke Energy Carolina
139 East Fourth Street
Cincinnati, OH 45201

The Cadmus Group, Inc.
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Table of Contents

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Introduction

This report addresses M&V activities for lighting retrofit energy conservation measures (ECMs) as part of the [redacted] Smart $aver custom incentive program application; specifically, the replacement of 760 parking lot lighting fixtures at eight locations in [redacted], NC.

ECM-1 – Replace Probe Start MH Fixtures with Pulse Start MH Fixtures

These measures involved replacing 716 1,000-watt standard probe-start metal halide (MH) fixtures with 320-watt pulse start MH fixtures (MHPS) and 44 400-watt standard probe-start MH fixtures with 200-watt MHPS fixtures. The installed fixture quantities were expected to be equal to the existing quantities.

Table 1 summarizes the proposed fixture installations.

Table 1. Proposed Lighting Fixture Installations

ECM	Qty	Measure	Location
1	23	1000W MH to 320W MHPS	redacted
2	5	1000W MH to 320W MHPS	redacted
3	34	1000W MH to 320W MHPS	redacted
4	24	1000W MH to 320W MHPS	redacted
5	21	1000W MH to 320W MHPS	redacted
6	12	1000W MH to 320W MHPS	redacted
7	113	1000W MH to 320W MHPS	redacted
8	179	1000W MH to 320W MHPS	redacted
9	135	1000W MH to 320W MHPS	redacted
10	170	1000W MH to 320W MHPS	redacted
11	8	400W MH to 200W MHPS	redacted
12	3	400W MH to 200W MHPS	redacted
13	14	400W MH to 200W MHPS	redacted
14	13	400W MH to 200W MHPS	redacted
15	6	400W MH to 200W MHPS	redacted
Total	**760**	-	-

Goals and Objectives

Table 2 shows projected savings goals identified in the project application.

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Table 2. Project Goals

ECM	Facility Name	Applicant		Duke Energy			
		Annual kWh Savings	Average kW Reduction*	Projected Annual kWh Savings**	Claimed Annual kWh Savings	Claimed Coincident Peak kW Reduction	Claimed Non-CP kW Reduction
1	redacted	55,861	-	-	74,597	0	1.03
2	redacted	12,144	-	-	16,217	0	0.22
3	redacted	82,578	-	-	110,274	0	1.52
4	redacted	58,290	-	-	77,840	0	1.08
5	redacted	51,004	-	-	68,110	0	0.94
6	redacted	29,145	-	-	38,920	0	0.54
7	redacted	274,450	-	-	366,499	0	5.07
8	redacted	434,748	-	-	580,560	0	8.03
9	redacted	327,882	-	-	437,853	0	6.05
10	redacted	412,889	-	-	551,370	0	7.62
11	redacted	6,433	-	-	8,591	0	0.12
12	redacted	2,412	-	-	3,221	0	0.04
13	redacted	11,258	-	-	15,033	0	0.21
14	redacted	10,454	-	-	13,960	0	0.19
15	redacted	4,825	-	-	6,443	0	0.09
Total	**-**	**1,774,372**	**N/A***	**2,516,923**	**2,369,488**	**0**	**32.76**

* The applicant's proposed demand reductions for individual measures are not clearly documented.
** Source: DSMore input spreadsheet.

The M&V project sought to verify the actual numbers for the following:

- Facility peak demand reduction (kW)
- Summer utility coincident peak demand reduction (kW)
- Annual energy savings (kWh)
- Annual realization rates (kW and kWh)

Project Contacts

The Duke Energy contact listed in Table 3 granted approval to plan and to schedule the site visit for this M&V effort.

Table 3. Project Contacts

Organization	Contact	Contact Information
Duke Energy	Frankie Diersing	p: 513-287-4096 Frankie.diersing@duke-energy.com
Cadmus	Christie Amero	p: 303-389-2509 Christie.amero@cadmusgroup.com
Customer	redacted	

Site Location

The locations where this project was installed are shown in Table 4.

Table 4. Project Locations

Location	Address	ECM
redacted	redacted	2, 12
redacted	redacted	3, 13
redacted	redacted	4
redacted	redacted	5, 14
redacted	redacted	6
redacted	redacted	7, 15
redacted	redacted	8
redacted	redacted	9
redacted	redacted	10
redacted	redacted	10
redacted	redacted	1, 11

M&V Option

To assess this project, Cadmus utilized IPMVP Option A.

Implementation

Cadmus reached out to the site contact provided by Duke Energy to review the evaluation plan and to schedule the site visit. As the site contact was based in a corporate office, he contacted general managers at the individual sites to explain the evaluation plan and alert them to the upcoming visit.

This project involved lighting retrofits at 11 different dealerships in seven separate locations across [redacted]. The on-site staff at most sites were car salespeople and not familiar with lighting fixture operations. At three sites ([redacted]), Cadmus spoke with facility managers who were familiar with the lighting fixture control strategy. The manager of the four [redacted] locations ([redacted]) said photosensors, located on facility roofs, controlled the fixtures. The [redacted] and [redacted] managers said the fixtures operated on timeclock control (set for 6:00 pm–7:00 am during winter and 7:00 pm–6:00 am during summer).

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All fixtures provided parking lot lighting and did not produce interactive effects with HVAC systems.

As the sites installed the same two fixture types, Cadmus installed a power meter at a single location. Light loggers could not be installed to verify operating hours due to the fixtures' outside location; weather and sunlight would either damage the meter or provide inaccurate measurements. Pole heights prevented Cadmus from accessing the fixtures' interiors.

Christie Amero and Tom Davis of Cadmus performed the site visits on January 8, 2016. Notably, site visits were performed on a cloudy, rainy day, which could have affected the status of exterior lighting fixtures.

Field Data

Cadmus visited all [redacted] locations to count fixtures and verify fixture and control types. One power meter was installed at the [redacted] location to verify electrical demand and operating hours on one lighting circuit. Table 5 summarizes total fixture counts at each location and fixture status at the time of inspection. Fixtures were on at the [redacted] and [redacted] locations during the inspection (~1:00 pm).

Fixture counts are based on Cadmus' walkthroughs of each property. Determining counts proved challenging as most properties bordered one another. For example, it was difficult to differentiate which fixtures should be considered on the [redacted] property or the [redacted] property.

Table 5. Summary of Lighting Fixture Counts and Control Strategies

ECM	Facility Name	Installed Fixture Description	Fixture Quantity		Status During Inspection	Control Strategy
			Proposed	Installed		
1	redacted	320W MH PS	23	22	Off	Timeclock, 6PM-7AM
2	redacted	320W MH PS	5	6	Off	
3	redacted	320W MH PS	34	41	ON	
4	redacted	320W MH PS	24	22	Off	
5	redacted	320W MH PS	21	64	Off	
6	redacted	320W MH PS	12	18	Off	
7	redacted	320W MH PS	113	82	Off	Timeclock, Time N/A
8	redacted	320W MH PS	179	177	Off	Photosensor
9	redacted	320W MH PS	135	134	Off	Photosensor
10	redacted	320W MH PS	170	152	Off	Photosensor
11	redacted	200W MHPS	8	4	Off	Timeclock, 6PM-7AM
12	redacted	200W MHPS	3	6	ON	
13	redacted	200W MHPS	14	14	ON	
14	redacted	200W MHPS	13	18	Off	

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ECM	Facility Name	Installed Fixture Description	Fixture Quantity		Status During Inspection	Control Strategy
			Proposed	Installed		
15	redacted	200W MHPS	6	22	Off	Timeclock, Time N/A
Total		**-**	**760**	**782**		

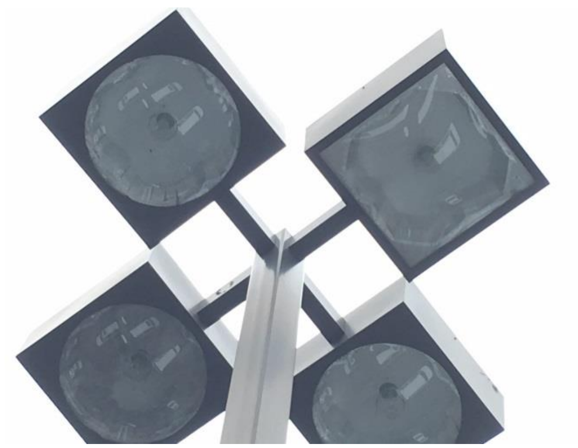
Cadmus also photographed installed parking lot fixtures at various locations. Figure 1 shows the parking lot at [redacted]. Figure 2 shows an energized lamp at [redacted] (which was forced on during the power meter installation). Figure 3 shows a two-fixture pole at the [redacted]. Figure 4 shows the four-fixture pole at [redacted].

Figure 1. [redacted] Parking Lot Fixtures

Figure 2. [redacted] Parking Lot Fixture – Lamp ON

Figure 3. [redacted] Parking Lot Fixture

Figure 4. [redacted] Parking Lot Fixture



Cadmus installed a three-phase, electric power meter on one exterior lighting circuit at [redacted], a circuit visually verified to feed five exterior lighting fixtures. Data were collected for two weeks at one-minute intervals. Table 6 summarizes the installed metering equipment;

Figure 5 shows the reading during Cadmus' verification of the circuit load.

Table 6. Summary of Installed Metering Equipment

Equipment ID	RX3000	WattNode 3D-480	Current Transducers (Qty/Size)
'OL Sect. 2' Circuit	1	1	3 / 50 A

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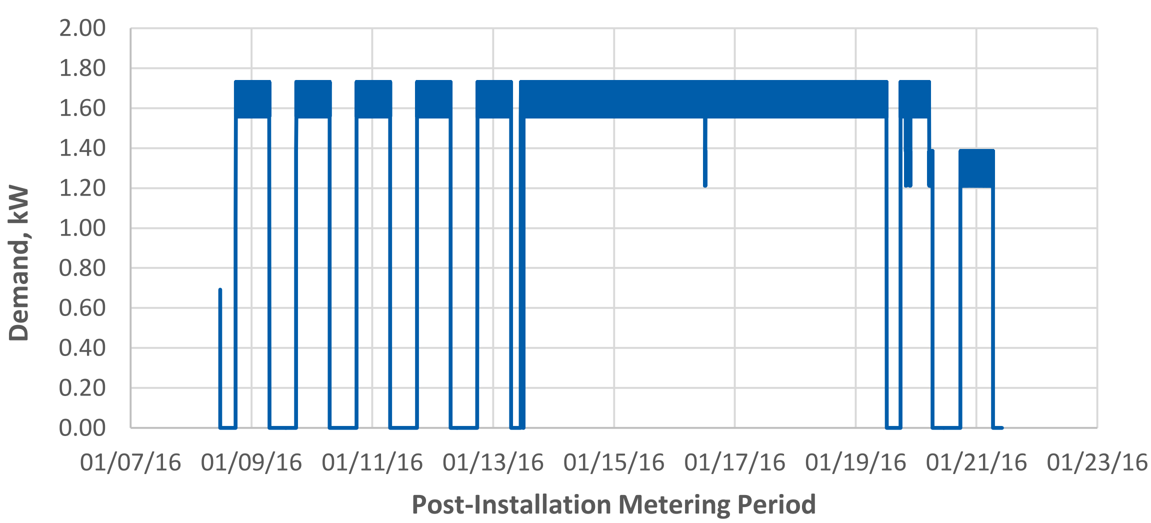
Figure 5. [redacted] Lighting Circuit Metering – Current Reading

Figure 6 summarizes the two weeks of metered power data for the lighting circuit, with an average operating demand of 1.61 kW. As the panel served five fixtures, measured watts per fixture were 323 W, which falls within 5% of the input wattage submitted in the application (340 W).

Based on the power metered data, it appears a photosensor controlled the fixtures, given fixtures turned on at slightly different times every day. During most days, fixtures turned on around 5:45 pm and turned off a little after 7:00 am. However, the fixtures stayed on 24 hours per day, from January 13 at ~11:00 am to January 19 at 12:00 pm. While the additional operating hours were initially unclear, the Martin Luther King holiday fell on January 18 in 2016; this is a popular holiday for automotive marketing and sales. Cadmus assumed the lights remained on during this time for marketing purposes.

Figure 6. [redacted] Installed Fixture Power Metering Data



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Data Accuracy

Table 7. Metering Equipment Accuracy

Measurement	Sensor	Accuracy	Notes
Demand, kW	WattNode Power Meter	±1%	
Current, amps	Magnelab CT	±1%	Recorded load must be < 130% and > 10% of CT rating

Data Analysis

Cadmus used the power metered data to verify the installed fixtures' electric demand. A combination of metered data, site observations, and discussions with site personnel were used to verify operating hours. Fixture counts were used to verify quantities installed.

As the fixture input wattage for the 320-watt pulse start MH fixtures was 5% less than that submitted in the application (323-watt vs. 340-watt), this ratio also applied to the 200-watt pulse start MH fixtures.

The lighting fixture at the [redacted] and [redacted] locations remained on during the 1:00 pm inspection. Therefore, these fixtures were assumed to operate all hours of the year (i.e., 8,760 hours).

As metered data for the [redacted] fixtures showed 24-hour operation during holidays, it was assumed other dealerships followed a similar schedule. Additional hours were added for three days around seven holidays: MLK Day, Presidents' Day, Memorial Day, Fourth of July, Labor Day, Columbus Day, and Thanksgiving weekend. Total annual operating hours for timeclock and photosensor controls were 4,629 hours. Evaluated installed case energy use was 1,204,780 kWh and average demand was 137.5 kW.

As Cadmus could not measure the power usage of the pre-retrofit fixtures, input wattages were based on rated input wattages shown in Table 57 of the Massachusetts 2015 Technical Reference Manual (the rated input wattage for a 400-watt metal halide is 455-watt, and the rated wattage for a 1,000-watt metal halide is 1,075-watt).

Annual operating hours of the pre-retrofit fixtures were assumed equal to the installed fixtures as changes were not made to the control strategy. Evaluated pre-retrofit annual energy use was 3,838,663 kWh and average demand was 438.2 kW.

Evaluated total annual energy savings were 2,633,883 kWh. The average (or noncoincident) demand reduction for all sites was 300.7 kW. The summer coincident peak demand reduction (July, Monday–Friday, 4:00 pm–5:00 pm) was 0.0 kW as exterior lighting fixtures were not operated during that period.

Conclusion

Cadmus found most lighting fixtures installed as expected. Slight variations in quantities occurred, which may have been due to evaluator counting errors. Annual operating hours were higher than expected, given fixtures at [redacted] appeared to operate 24 hours per day during holiday weekends, and fixtures at [redacted] and [redacted] remained on during the middle of the day.

The fixture input wattage for the 320-watt pulse start MH fixtures was slightly lower than expected (5% less). This reduction in input wattage was applied to the 200-watt fixtures.

The overall energy savings realization rate was 111%; the summer coincident peak demand reduction (July, Monday–Friday, 4:00 pm–5:00 pm) was 100%; and the average (or noncoincident) peak demand reduction realization rate was 918%.

Table 8 provides a comparison of the applicant, Duke Energy claimed, and evaluation energy savings and demand reduction. Table 9 provides the realization rates compared to energy savings and demand reductions claimed by Duke Energy.

Table 8. Comparison of Applicant, Duke Energy Claimed, and Evaluation Energy Savings and Demand Reduction

ECM	Applicant	Duke Energy Claimed			Evaluation		
	Annual kWh Savings	Annual kWh Savings	CP kW Reduction	Non-CP kW Reduction	Annual kWh Savings	CP kW Reduction	Non-CP kW Reduction
1	55,861	74,597	0	1.03	81,571	0.00	9.31
2	12,144	16,217	0	0.22	15,913	0.00	1.82
3	82,578	110,274	0	1.52	204,185	0.00	23.31
4	58,290	77,840	0	1.08	86,548	0.00	9.88
5	51,004	68,110	0	0.94	8,823	0.00	1.01
6	29,145	38,920	0	0.54	32,808	0.00	3.75
7	274,450	366,499	0	5.07	439,766	0.00	50.20
8	434,748	580,560	0	8.03	626,126	0.00	71.48
9	327,882	437,853	0	6.05	471,458	0.00	53.82
10	412,889	551,370	0	7.62	618,714	0.00	70.63
11	6,433	8,591	0	0.12	13,105	0.00	1.50
12	2,412	3,221	0	0.04	1,323	0.00	0.15
13	11,258	15,033	0	0.21	30,988	0.00	3.54
14	10,454	13,960	0	0.19	10,524	0.00	1.20
15	4,825	6,443	0	0.09	-7,968	0.00	-0.91
Total	**1,774,372**	**2,369,488**	**0**	**32.76**	**2,633,883**	**0.00**	**300.67**

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Table 9. Energy Savings and Demand Reduction Realization Rates

ECM	Annual kWh Savings	Coincident Peak kW	Non-CP kW
1	109%	NA	904%
2	98%	NA	826%
3	185%	NA	1533%
4	111%	NA	915%
5	13%	NA	107%
6	84%	NA	694%
7	120%	NA	990%
8	108%	NA	890%
9	108%	NA	890%
10	112%	NA	927%
11	153%	NA	1247%
12	41%	NA	378%
13	206%	NA	1685%
14	75%	NA	632%
15	-124%	NA	-1011%
Total	**111%**	NA	**918%**

Application ID 14-1654031
Lighting Replacement:
M&V Report

August 5, 2016

Duke Energy Carolina
139 East Fourth Street
Cincinnati, OH 45201

The Cadmus Group, Inc.
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CADMUS

Prepared by:
Dave Korn
Christie Amero
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Introduction

This report addresses M&V activities for lighting retrofit energy conservation measures (ECMs), conducted as part of the [redacted] Smart $aver custom incentive program application; specifically, the replacement of fluorescent T5 lighting fixtures with high-output T5 (T5-HO) lighting fixtures.

ECM-1—Replace Fluorescent T5 Lighting Fixtures with T5-HO Fixtures

The measure includes replacing 453 six-lamp, 351-watt T5 lighting fixtures with 453 225-watt T5-HO lighting fixtures.

Goals and Objectives

Table 1 shows projected savings goals identified in the project application.

Table 1. Project Goals

Applicant		Duke Energy		
Annual kWh Savings	Avg. Demand Reduction, kW	Claimed Annual kWh savings	Claimed Coincident Peak kW Reduction	Claimed Non-CP kW Reduction
354,112	57	337,186	55.8	55.8

The M&V project sought to verify actual numbers for the following:

- Facility peak demand reduction (kW)
- Summer utility coincident peak demand reduction (kW)
- Annual energy savings (kWh)
- Annual realization rates (kW and kWh)

Project Contacts

The Duke Energy contact listed in Table 2 granted approval to plan and to schedule the site visit for this M&V effort.

Table 2. Project Contacts

Organization	Contact	Contact Information
Duke Energy	Frankie Diersing	office: 513-287-4096 Frankie.diersing@duke-energy.com
Cadmus	Christie Amero	office: 303-289-2509 christie.amero@cadmusgroup.com
Customer	redacted	

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Site Location

The location where this measure was installed is shown in Table 3.

Table 3. Project Location

Address	ECM
redacted	1

M&V Option

To assess this project, Cadmus utilized IPMVP Option A.

Implementation

Cadmus reached out to the site contact provided by Duke Energy to review the evaluation plan and to schedule the site visit. Tom Davis of Cadmus performed the site visit on January 5, 2016.

Field Notes

During the site visit, Cadmus photographed fixture information, conducted a survey with facility personnel, and installed lighting loggers. The facilities operates seven days per week, and its schedule did not change after the installation. The site visit determined 432 fixtures were installed and not the originally reported 453.

Field Data

Cadmus installed 15 light loggers to meter the facility for two weeks; these data were then used to estimate annual hours of operation. Table 4 summarizes the light logger data.

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Table 4. Summary of Meter Data

Meter S/N	Location	Metered Hours	Operating Hours	Percentage Operating	Projected Annual Operating Hours	Coincidence Factor
10374190	Break room	322	224	70%	6,092	100%
10374194	Back aisle - row #28	322	223	69%	6,066	100%
10374220	Receiving area - back right	322	218	68%	5,945	100%
10380395	Aisle 6	322	223	69%	6,070	100%
10380397	Showroom/aisle 99	322	225	70%	6,120	100%
10380400	Office area	322	223	69%	6,079	100%
10380405	Aisle 46 - bay #14	322	211	66%	5,746	100%
10380408	Aisle 27	322	219	68%	5,975	100%
10380409	Aisle 22	322	219	68%	5,964	100%
10380410	Aisle 14	322	173	54%	4,710	100%
10380415	Training/conference room	322	190	59%	5,184	99%
10380416	Automotive room	322	223	69%	6,080	100%
10380545	Front area aisle	322	211	66%	5,755	95%
10380612	Aisle 43	322	223	69%	6,065	100%
10380615	Aisle 8	322	211	66%	5,750	100%

Data Analysis

In the original analysis, annual operating hours for all fixtures were assumed to be approximately 6,049 hours. Cadmus averaged the projected annual hours of operation of all light loggers installed and applied the resulting estimates to calculate savings. On average, lights were projected to operate 5,840 hours annually. These values were applied to demand values and quantities confirmed on site to calculate savings, shown in Table 5. Additionally, Cadmus averaged peak coincidence factors for each space type and used these values to calculate peak demand reductions and applied waste heat factors to final numbers to account for HVAC interactive effects.

Table 5. Savings Calculations

Annual Operating Hours	Fixture Quantity	CF	Demand, kW		Energy Savings		
			Pre	Post	Average kW Reduction	CP kW Reduction	Annual kWh
5,840	432	100%	0.4	0.2	68.5	68.5	372,877

Conclusion

Cadmus found 21 fewer fixtures installed than expected. The energy savings realization rate was 111% compared to the Duke Energy claimed savings. The summer peak demand and noncoincident peak demand realization rates were calculated at 123%.

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Table 6 provides a comparison of the applicant, Duke Energy claimed, and evaluation energy savings and demand reduction. Table 7 provides the realization rates compared to energy savings and demand reductions claimed by Duke Energy.

Table 6. Evaluation Energy Savings and Demand Reduction

Applicant		Duke Energy Claimed			Evaluation		
Annual kWh Savings	Avg. kW Reduction	Annual kWh Savings	Coincident Peak kW Reduction	Non-CP kW Reduction	Annual kWh Savings	Coincident Peak kW Reduction	Non-CP kW Reduction
354,112	57	337,186	55.8	55.8	372,877	68.5	68.5

Table 7. Energy Savings and Demand Reduction Realization Rates

Annual kWh Savings	Coincident Peak kW	Non-CP kW
111%	123%	123%

Application ID 13-1594680 Lighting Replacement: M&V Report

August 5, 2016

Duke Energy Carolinas
139 East Fourth Street
Cincinnati, OH 45201

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Introduction

This report addresses M&V activities for a lighting retrofit energy conservation measure (ECM), conducted as part of the [redacted] Smart $aver custom program application; specifically, the replacement of 157 metal halide lighting fixtures with 105 LED lighting fixtures.

Cadmus based the following facility and measure descriptions on the original project documentation.

ECM-1—Replace Metal Halide Fixtures with LED Lighting Fixtures

The measure involved replacing 157, 455-Watt, metal halide (MH) lighting fixtures with 105, six-lamp, 150-Watt LED fixtures. The customer applied for Smart $aver prescriptive incentives for motion sensors under a different application.

Goals and Objectives

Table 1 shows projected savings goals identified in the project application.

Table 1. Project Goals

Applicant		Duke Energy			
Annual kWh Savings	Avg. kW Reduction	Projected Annual kWh Savings*	Claimed Annual kWh Savings	Claimed Coincident Peak kW Reduction	Claimed Non-CP kW Reduction
524,990	60	490,528	490,520	56	56

* Source: DSMore input spreadsheet.

The M&V project sought to verify the actual numbers for the following:

- Facility peak demand reduction (kW)
- Summer utility coincident peak demand reduction (kW)
- Annual energy savings (kWh)
- Annual realization rates (kW and kWh)

Project Contacts

The Duke Energy contact listed in Table 2 granted approval to plan and to schedule the site visit for this M&V effort.

Table 2. Project Contacts

Organization	Contact	Contact Information
Duke Energy	Frankie Diersing	p: 513-287-4096 frankie.diersing@duke-energy.com
Cadmus	Christie Amero	office: 303-389-2509 christie.amero@cadmusgroup.com
Customer	redacted	

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Site Location

The location where this measure was installed is shown in Table 3.

Table 3. Project Location

Address	ECM
redacted	1

M&V Option

To assess this project, Cadmus utilized IPMVP Option A.

Implementation

Cadmus reached out to the site contact provided by Duke Energy to review the evaluation plan and to schedule the site visit. Christie Amero of Cadmus performed the site visit on January 7, 2016.

Field Lighting Survey

During the site visit, Cadmus met with the facility manager to review the attached lighting survey and to collect general operating information.

The facility produces prepackaged chicken products. Production runs 24 hours per day, Monday through Friday, but cleaners and maintenance personnel occupy the spaces during the weekends. The site contact estimated that lighting fixtures operate 24/7. The site observes four or five standard holidays per year.

There are a few occupancy sensors in the offices, small storage areas, and gowning areas, but the new fixtures were installed in the production areas. The facility has no photosensors.

The production area is served by an ammonia refrigeration system.

The site contact noted there has been a mix of increased and decreased light levels since the project implementation. Staff have reported that the light output seems brighter but has less range.

Field Data

After completing the lighting survey, Cadmus performed a walkthrough of the facility to verify and count the new lighting fixtures. Because the lighting fixtures are located in cooler or freezer spaces with daily spray-downs, no light loggers could be installed. Figure 1 shows installed LED lighting fixtures in the refrigerated warehouse space. Table 4 summarizes the installed lighting fixture counts.

Figure 1. Refrigerated Warehouse LED Lighting Fixtures

Table 4. Installed Lighting Fixture Counts

#	Location Description	Installed Lighting Fixtures	
		Description	Quantity
1	Line 3 - 1st Room (Cooler)	LED MH Replacement, Wet Location	8
2	Line 3 - 2nd Room (Cooler)	LED MH Replacement, Wet Location	4
3	Line 3 - Pack Out	LED MH Replacement, Wet Location	3
4	Clean Room - #1	LED MH Replacement, Wet Location	1
5	Clean Room - Hall	LED MH Replacement, Wet Location	2
6	Clean Room - #3	LED MH Replacement, Wet Location	4
7	Line 1 - Marination	LED MH Replacement, Wet Location	15
8	Line 1 - Main	LED MH Replacement, Wet Location	7
9	Line 1 - Hall	LED MH Replacement, Wet Location	3
10	Battery Room	LED MH Replacement, Wet Location	4
11	Raw Process / Marination	LED MH Replacement, Wet Location	14
12	Shipping - 1	LED MH Replacement, Wet Location	5
13	Shipping - 2	LED MH Replacement, Wet Location	8
14	Storage Ingredients	LED MH Replacement, Wet Location	3
15	Hallway to Cooler	LED MH Replacement, Wet Location	3
16	Exterior Dock	LED MH Replacement, Wet Location	2
17	Freezer	LED MH Replacement, Wet Location	6
18	Cooler (Back)	LED MH Replacement, Wet Location	11
19	New Shipping Dock	LED MH Replacement, Wet Location	8
20	Line 1 - Clean Room	LED MH Replacement, Wet Location	4
Total	-	-	**115**

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Data Analysis

Cadmus used the survey data and manufacturer's data to verify the power demand and operating hours of the controlled equipment. The installed fixture was confirmed to be the high-bay, CPS-HBL, 150-Watt LED fixture, listed on the Design Lights Consortium's (DLC) list of certified LED fixtures. The DLC lists the fixture input wattage as 152 Watts. The total number of installed fixtures, based on the walkthrough, are 115 fixtures. Based on the discussion with the facility manager, annual operating hours are 8,760 hours.

The evaluated installed lighting energy use is 153,125 kWh, with 17.5 kW annual average demand.

As Cadmus could not measure the power usage of the pre-retrofit fixtures, input wattages were based on the rated input wattages in Table 57 of the Massachusetts 2015 Technical Reference Manual. According to the TRM, the rated input wattage for a 400-Watt metal halide is 455 W.

Annual operating hours of the pre-retrofit fixtures were assumed equal to the installed fixtures as changes had not been made to the control strategy. The quantity was assumed equal to that assumed in the original study (i.e., 157 fixtures). Evaluated pre-retrofit lighting annual energy use is 625,771 kWh, and annual average demand is 71.4 kW.

The lighting fixture annual energy savings are 472,646 kWh; the average demand reduction is 54.0 kW.

Since the lighting retrofit was performed in refrigerated spaces, additional energy savings result from reduced load on the cooling system. The energy savings and demand reduction with HVAC interactions were calculated using the following equations for cooler and freezer LEDs in the Massachusetts Technical Reference Manual (TRM):

$$\text{Cooling Annual Energy Savings, kWh} = \text{Lighting Fixture Annual Energy Savings, kWh} * 0.28 * \text{Efficiency of Refrigeration System, kW/ton}$$

Where:

Lighting Fixture Annual Energy Savings, kWh = 472,646 kWh

0.28 = Conversion from kW and tons (3,412 Btuh/kW ÷ 12,000 Btuh/ton)

Efficiency of Refrigeration System, kW/ton = 0.8 kW/ton (assumption for ammonia system)

The cooling annual energy savings are 105,873 kWh and the demand reduction is 12.1 kW.

The evaluated total annual energy savings are 578,518 kWh. The annual average (or noncoincident) demand reduction is 66.0 kW. The summer coincident peak demand reduction (July, Monday–Friday, 4:00 pm–5:00 pm) is also 66.0 kW.

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Conclusion

Cadmus found the LED lighting fixture type installed as expected with a slight increase in installed fixture quantity (115 fixtures versus 105 fixtures). The overall energy savings realization rate was 118%, compared to the Duke Energy claimed savings. The summer peak demand realization rate was calculated as 118% and the annual average (or noncoincident) peak demand reduction realization rate was also 118%.

While the installed fixture quantity increased, the evaluated energy savings account for reduced load on the refrigeration system, which was not accounted for in the original analysis.

Table 5 provides a comparison of the applicant, Duke Energy claimed, and evaluation energy savings and demand reduction. Table 6 provides realization rates compared to energy savings and demand reductions claimed by Duke Energy.

Table 5. Comparison of Applicant, Duke Energy Claimed, and Evaluation Energy Savings and Demand Reduction

Applicant		Duke Energy Claimed			Evaluation		
Annual kWh Savings	Avg. kW Reduction	Annual kWh Savings	Coincident Peak kW Reduction	Non-CP kW Reduction	Annual kWh Savings	Coincident Peak kW Reduction	Non-CP kW Reduction
524,990	60	490,520	56.0	56.0	578,518	66.0	66.0

Table 6. Energy Savings and Demand Reduction Realization Rates

Annual kWh Savings	Coincident Peak kW	Non-CP kW
118%	118%	118%

Application ID 14-1658121
Lighting
M&V Report

November 16, 2016

Duke Energy
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Introduction

This report outlines Cadmus' measurement and verification (M&V) activities for five retrofit energy conservation measures (ECMs) as part of the [redacted], Smart $aver custom incentive program application—specifically for replacing 3,384 fluorescent T12 lighting fixtures with T8 lighting fixtures at one location in [redacted], North Carolina. Energy savings were expected to result from the reduced fixture input wattage. Descriptions of the ECMs as submitted in the application documentation are provided below.

ECMs: Replace Fluorescent T12 Fixtures with T8 Fixtures

[Redacted] is a property management company, located in [redacted], North Carolina. [Redacted] is a 281,226 square-foot, 19-story office building with an attached parking garage. Business hours are Monday through Friday, 7:00 a.m. to 7:00 p.m., and cleaning occurs on weekdays from 6:00 p.m. to 2:00 a.m. There is minimal weekend use; the original analysis estimated that 10% of the office lighting fixtures are used for a total of eight hours on weekends. The hallway, restroom, and parking garage lighting fixtures operate round the clock, all week. The annual electricity energy use is approximately 7,080,000 kWh, based on 2013 and 2014 utility data.

[Redacted] decided to replace fluorescent T12 lighting fixtures in offices, hallways, restrooms, and the parking garage with lower-wattage T8 fixtures. Table 1 summarizes pre-retrofit and installed lighting fixtures included in the five ECMs. All lighting fixtures were installed with Consortium for Energy Efficiency-qualified lamps and ballasts.

Table 1. Summary of Lighting ECMs

ECM	Location	Annual Operating Hours	Pre-Retrofit		Installed	
			Fixture Description	Quantity	Fixture Description	Quantity
1	Offices	4,680	3-lamp, 4-foot T12	2,268	2-lamp, 4-foot T8	2,268
2	Hallway	8,760	3-lamp, 4-foot T12	561	2-lamp, 4-foot T8	561
3	Restrooms	8,760	2-lamp, 4-foot T12	242	2-lamp, 4-foot T8	242
4	Parking Deck	8,760	2-lamp, 8-foot T12	198	4-lamp, 4-foot T8	198
5	Parking Deck	8,760	2-lamp, 4-foot T12	115	2-lamp, 4-foot T8	115
Total	-	-	-	**3,384**	-	**3,384**

Goals and Objectives

Table 2 shows the projected savings goals identified in the project application.

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Table 2. Project Goals

ECM	Application		Duke Energy			
	Annual kWh Savings	Average kW Reduction	Projected Annual kWh Savings*	Claimed Annual kWh Savings	Claimed Coincident Peak kW Reduction	Claimed Non-CP kW Reduction
1	1,114,495	N/A	705,257	686,352	150.70	65.97
2	516,008	N/A	491,436	491,427	56.10	56.07
3	116,596	N/A	116,596	116,594	13.31	13.30
4	154,369	N/A	133,555	133,553	15.25	15.24
5	53,392	N/A	48,355	48,354	5.52	5.52
Total	**1,954,860**	**N/A**	**1,495,199**	**1,476,280**	**240.87**	**156.10**

* Source: DSMore input spreadsheet.

For this M&V project, Cadmus sought to verify actual numbers for the following:

- Facility peak demand reduction (kW)
- Summer utility coincident peak demand reduction (kW)
- Annual energy savings (kWh)
- Annual realization ratios (kW and kWh)

Project Contacts

Table 3 lists the Duke Energy contact who granted Cadmus approval to plan and schedule the site visit for this M&V effort, along with the Cadmus contact and the customer contact.

Table 3. Project Contacts

Organization	Contact	Contact Information
Duke Energy	Monica Redman, Senior DSM & Retail Programs Analyst	monica.redman@duke-energy.com
Cadmus	Christie Amero, Senior Analyst	office: 303-389-2509 christie.amero@cadmusgroup.com
Customer	redacted	

Site Location

The site location is listed in Table 4.

Table 4. Site Location

Address	ECM
redacted	1 through 5

M&V Option

To assess this site, Cadmus followed IPMVP Option A.

Implementation

Cadmus reached out to the site contact provided by Duke Energy to review the evaluation plan and schedule the site visit. Christie Amero of Cadmus performed the site visit on June 23, 2016.

Field Survey

During the site visit, Cadmus met with the facility manager to review the lighting survey and to collect general operating information. Each floor of the 19-story building is composed of a central lobby area, hallways, and common bathrooms. Various tenant offices spaces wrap around the common areas. Five central elevators serve the 19 floors.

The facility operates Monday through Friday, from 6:00 a.m. to 12:00 a.m., year round. The building is closed on weekends and observes 10 standard holidays per year. Lighting fixtures in the common areas (lobbies, hallways, and bathrooms) are controlled by a timeclock. The current timeclock setting is 6:00 a.m. to 12:00 a.m., Monday through Friday. The cleaning crews and security staff are in change of turning fixtures in the private offices spaces on and off at the end of each day. There are no occupancy sensors in the common areas or offices.

The parking garage lighting fixtures are on both photocell and timeclock control. Each parking level has four rows of lighting fixtures: two in the center of the garage and one close to the exterior on each side. The lights in rows near the exterior are mostly off during daylight hours, based on the light level. The rows in the center are on during daylight hours since that area does not receive direct sunlight. All of the parking garage lighting is off from 12:00 a.m. to 6:00 a.m. when the building is closed.

Cooling for the building is provided by two 370-ton Trane water-cooled chillers, both of which are over 20 years old. The cooling system uses air-side economizer controls to provide free-cooling when outside air conditions allow. Conditioned air is distributed to the spaces via variable air volume boxes with electric reheat coils.

The facility manager confirmed that the site has retrofitted approximately 85% to 90% of the pre-retrofit T12 lamps with T8 lamps. They still use T12s in a few stairwells and storage rooms.

During the interview, the facility manager stated that in general, they have received positive feedback regarding the lighting retrofit and have noticed an improvement in lighting quality. However, some tenants have complained that the new T8 fixtures are too bright, so the facility staff removed some of the T8 lamps in a few offices.

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Field Data

ECMs: Replace Fluorescent T12 Fixtures with T8 Fixtures

After completing the lighting survey, Cadmus performed a walkthrough of the facility to verify the installed lamp types and to install light loggers. Since the site still uses the pre-retrofit T12 lamps in a few stairwells and storage rooms, Cadmus was able to record the make and model for both the pre-retrofit and installed lamps. Figure 1 shows the make and model number of the new 4-foot T8 lamps that were installed throughout the building. The 4-foot Philips F32T8/ADV835/EW lamps have an of 28 watts.

Figure 2 shows the make and model number of the new Philips ADVANCE ICN-2P32-N electronic ballast and Figure 3 shows the ballast specifications.

Figure 4 shows an installed two-lamp, 2-foot by 4-foot T8 troffer lighting fixture, which is typical throughout the facility.

Figure 1. Installed Philips 28-Watt F32T8 Lamp

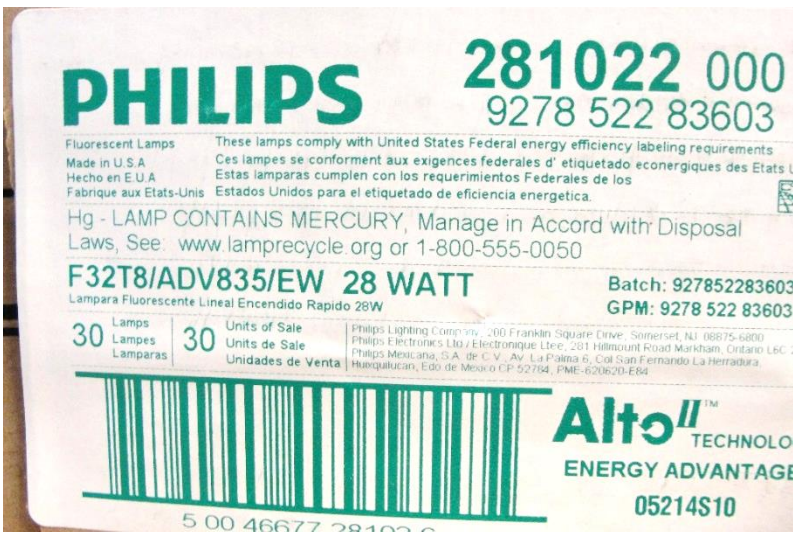

Figure 2. Installed Philips ADVANCE Electronic Ballast

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Figure 3. Installed Philips Electronic Ballast Specifications

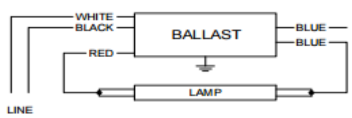
ADVANCE TRANSFORMER CO.

Electrical Specifications

ICN-2P32-N @ 120V	
Brand Name	**CENTIUM**
Ballast Type	**Electronic**
Starting Method	**Instant Start**
Lamp Connection	**Parallel**
Input Voltage	**120-277**
Input Frequency	**50/60 HZ**
Status	**Active**

Lamp Type	Num. of Lamps	Rated Lamp Watts	Min. Start Temp (°F/C)	Input Current (Amps)	Input Power (ANSI Watts)	Ballast Factor	MAX THD %	Power Factor	MAX Lamp Current Crest Factor	B.E.F.
* F17T8	1	17	0/-18	0.17	21	1.08	10	0.99	1.6	5.14
F17T8	2	17	0/-18	0.26	32	0.90	10	0.99	1.6	2.81
F25T8	1	25	0/-18	0.24	29	1.05	10	0.99	1.6	3.62
F25T8	2	25	0/-18	0.38	45	0.89	10	0.99	1.6	1.98
F32T8	1	32	0/-18	0.31	37	1.05	10	0.99	1.6	2.84
F32T8	2	32	0/-18	0.49	56	0.89	10	0.99	1.6	1.59
F32T8/ES (25W)	1	25	60/16	0.24	28	1.05	10	0.99	1.6	3.75
F32T8/ES (25W)	2	25	60/16	0.38	45	0.92	10	0.99	1.6	2.04
F32T8/ES (28W)	1	28	60/16	0.24	31	1.03	10	0.99	1.6	3.32
F32T8/ES (28W)	2	28	60/16	0.41	48	0.89	10	0.99	1.6	1.85
F32T8/ES (30W)	1	30	60/16	0.28	33	1.03	10	0.98	1.6	3.12
F32T8/ES (30W)	2	30	60/16	0.45	54	0.89	10	0.99	1.6	1.65
F40T8	1	40	32/00	0.35	42	1.00	10	0.98	1.6	2.38

Wiring Diagram



Diag. 68

Insulate unused blue lead for 1000V

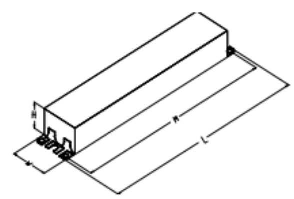
The wiring diagram that appears above is for the lamp type denoted by the asterisk (*)

Standard Lead Length (inches)

	in.	cm.
Black	24	61
White	24	61
Blue	28	71.1
Red	45	114.3
Yellow		0
Gray		0
Violet		0

	in.	cm.
Yellow/Blue		0
Blue/White		0
Brown		0
Orange		0
Orange/Black		0
Black/White		0
Red/White		0

Enclosure



Enclosure Dimensions

OverAll (L)	Width (W)	Height (H)	Mounting (M)
9.5 "	1.3 "	1.0 "	8.9 "
9 1/2	1 3/10	1	8 9/10
24.1 cm	3.3 cm	2.5 cm	22.6 cm

Figure 4. Installed 2-Lamp 2-Foot by 4-Foot T8 Troffer

Figure 5 shows the make and model number of the pre-retrofit T12 lamp used in the common bathrooms, storage areas, and mechanical rooms. Figure 6 shows the make and model number of the pre-retrofit T12 lamp used in the offices and hallways.

Figure 5. Pre-Retrofit T12 Lamp – Bathrooms and Mechanical Rooms

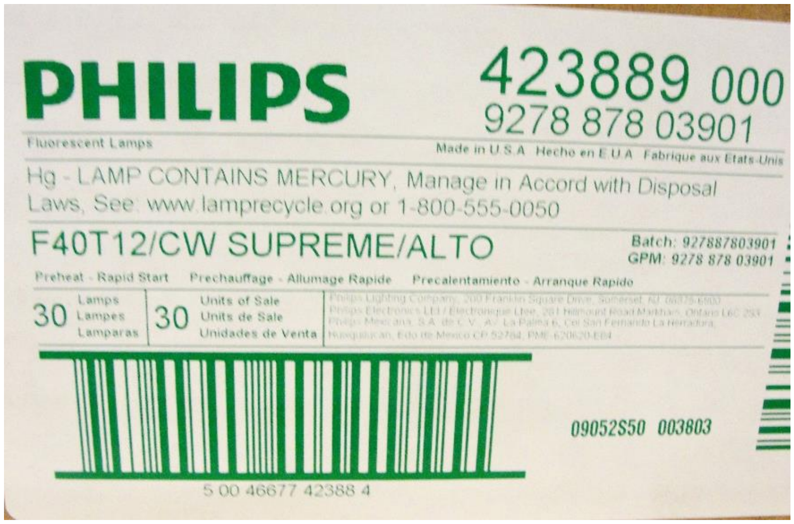
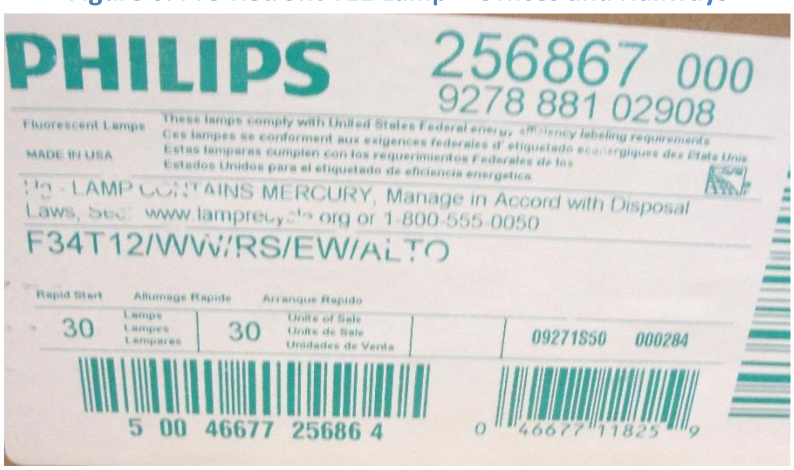


Figure 6. Pre-Retrofit T12 Lamp – Offices and Hallways



Cadmus installed eight light loggers on four floors of the facility (two per floor) and two loggers in the parking garage to collect fixture operating hours for a three-week period. Table 5 summarizes the locations of the light loggers and the monitored fixture types.

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Table 5. Summary of Fixture Counts and Installed Light Loggers

#	Floor	Location	Installed Fixture Description	Light Logger Serial Number
1	12	'United Guaranty' Office	2-lamp, 2-foot by 4-foot T8 troffer	10261581
2		Women's Restroom	3-lamp, 2-foot by 4-foot T8 troffer	10326559
3	17	Office	2-lamp, 2-foot by 4-foot T8 troffer	10272067
4		Common Area Hallway, Near Elevators	2-lamp, 2-foot by 4-foot T8 troffer	10272105
5	7	Office	2-lamp, 2-foot by 4-foot T8 troffer	10268223
6		Cubicles	2-lamp, 2-foot by 4-foot T8 troffer	10327029
7	3	Main Hallway	2-lamp, 2-foot by 4-foot T8 troffer	10326687
8		Private Office	2-lamp, 2-foot by 4-foot T8 troffer	10162076
9	Parking Garage	P2, Exterior Row, Level L	2-lamp, 4-foot T8 strip	10332054
10		P2, Interior Row, Level L	2-lamp, 4-foot T8 strip	10261597

Figure 7 through Figure 10 show the approximate locations (in red) where Cadmus installed light loggers on each floor of the building.

Figure 7. Floor 3 Light Logger Installation Locations

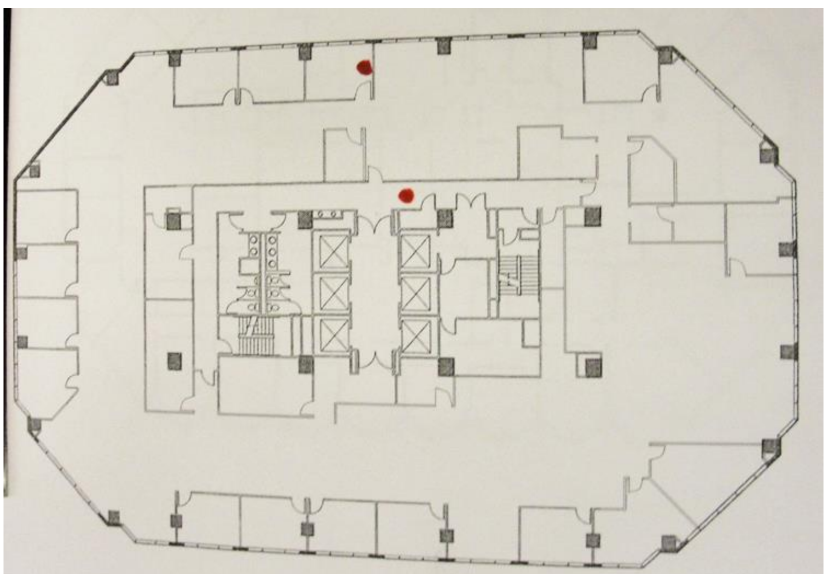

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Figure 8. Floor 7 Light Logger Installation Locations

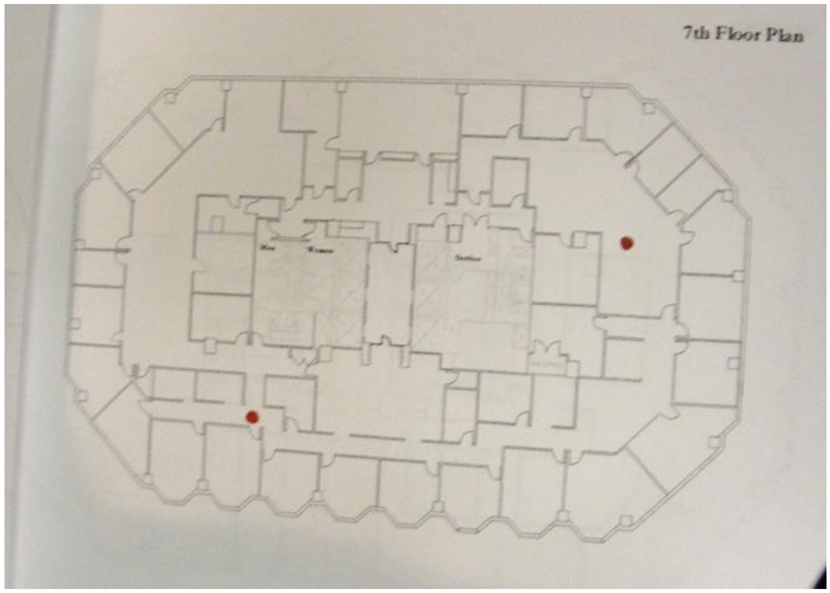

Figure 9. Floor 12 Light Logger Installation Locations

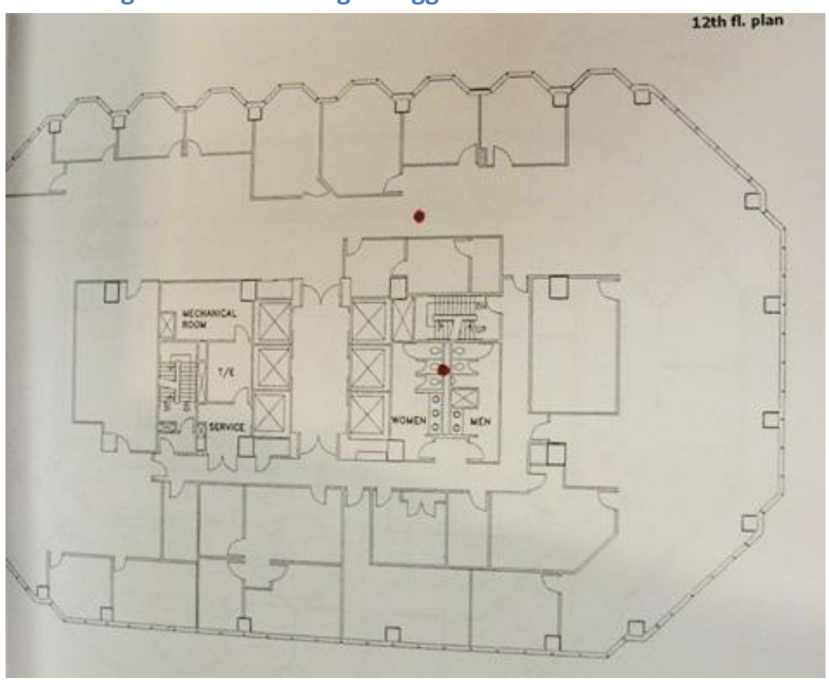

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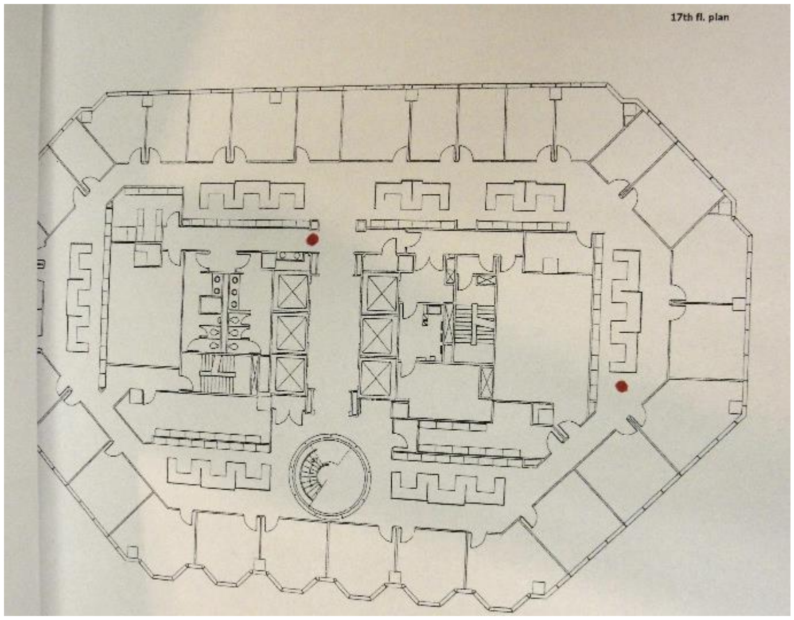
Figure 10. Floor 17 Light Logger Installation Locations



Data Analysis

ECMs: Replace Fluorescent T12 Fixtures with T8 Fixtures

Cadmus used the survey and light logger data to verify demand and operating hours for the installed lighting fixtures. Table 6 summarizes the light logger data.

Table 6. Summary of Light Logger Data

#	Floor	Location	Total Metered Hours	Total Operating Hours	Percentage Operating	Average Coincidence Factor
1	12	Office	614.9	321.9	52%	100%
2		Restroom	614.8	222.8	36%	100%
3	17	Office	614.6	197.5	32%	100%
4		Hallway	614.5	614.5	100%	100%
5	7	Office	614.6	208.6	34%	100%
6		Cubicles	614.6	207.7	34%	100%
7	3	Hallway	614.7	350.0	57%	100%
8		Office	614.7	96.5	16%	58%
9	Parking Garage	Exterior Row	613.3	304.8	50%	0%
10		Interior Row	614.6	614.6	100%	100%

Cadmus averaged the logger data for each space type and extrapolate to estimate annual operating hours and the peak coincidence factor:

- The five loggers in tenant office areas produced a mean projected annual runtime of 2,942 hours and a mean coincidence factor of 92%
- The two loggers in hallways produced a mean projected annual runtime of 6,874 hours and a mean coincidence factor of 100%
- The one logger in a restroom produced a projected annual runtime of 3,175 hours and a coincidence factor of 100%
- The two loggers in the parking garage produced a mean projected annual runtime of 6,557 hours and a mean coincidence factor of 50%

Based on the installed lamp and ballast model numbers collected on site, the total fixture input for the two-lamp, 2-foot by 4-foot T8 fixtures is 48 watts, and the total input for the four-lamp, 4-foot T8 fixtures is 94 watts. Cadmus adjusted the pre-retrofit T12 fixture wattages slightly based on the T12 lamp model numbers collected on site and technical reference manual rated wattages tables. We assumed that the pre-retrofit and installed case fixture quantities were equal to the original application based on sample area counts during the site visit.

The energy savings and peak demand reduction without HVAC interactive effects are 1,053,727 kWh and 236.91 kW, respectively.

Cadmus also calculated energy savings and demand reductions for interior fixtures with HVAC interactive effects, based on the heating and cooling system type collected on site. Cadmus used the waste heat factors listed in TechMarket Works' Process and Impact Evaluation of the Non-Residential Smart $aver® Prescriptive Program in the Carolina System: Lighting and Occupancy Sensors report submitted in April 2013. The energy waste heat factor for a small office near Greensboro, North Carolina with air conditioner cooling, an economizer, and electric heating is -0.032 and the demand factor is 0.136. The following equation is used to calculate savings with HVAC interactions:

$$kWh_{savings\ with\ HVAC} = kWh_{savings}\ x\ (1 + WHFe)$$

$$kW_{savings\ with\ HVAC} = kW_{savings}\ x\ (1 + WHFd)$$

Where:

WHFe = Waste heat factor for energy (= -0.032)

WHFd = Waste heat factor for demand (= 0.136)

The total evaluated energy savings were 1,025,314 kWh. The evaluated total summer coincident peak demand reduction (for the month of July, Monday through Friday from 4:00 p.m. to 5:00 p.m.) was 267.41 kW, and the average, or non-coincident, peak demand reduction was 117.04 kW.

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Conclusion

While on the site, Cadmus found the equipment installed as expected. The overall energy savings realization rate was 69%, compared to Duke Energy claimed savings. The summer peak demand realization rate was calculated as 111%. The average (or non-coincident) peak demand reduction realization rate was 75%.

The most significant impact to energy savings was the reduction in annual operating hours. The evaluated annual operating hours for lighting fixtures in offices, hallways, and restrooms were 63%, 78%, and 36%, respectively, of those claimed in the original application. The evaluated average annual operating hours for the parking garage lighting fixtures were 75% of that claimed in the original application. The installed fixture wattages were also higher than that claimed in the original application, and pre-retrofit fixture wattages were lower.

Table 7 provides a comparison of the applicant, Duke Energy claimed, and Cadmus evaluated energy savings and demand reduction. Table 8 provides realization rates comparing energy savings and demand reductions claimed by Duke Energy to those calculated by Cadmus.

Table 7. Comparison of Applicant, Duke Energy Claimed, and Evaluation Energy Savings and Demand Reduction

ECM	Applicant		Duke Energy Claimed			Evaluation		
	Annual kWh Savings	Average kW Reduction	Annual kWh Savings	Coincident Peak kW Reduction	Non-CP kW Reduction	Annual kWh Savings	Coincident Peak kW Reduction	Non-CP kW Reduction
1	1,114,495	N/A	686,352	150.70	65.97	529,608	193.71	60.46
2	516,008	N/A	491,427	56.10	56.07	306,101	52.26	34.94
3	116,596	N/A	116,594	13.31	13.30	23,798	8.80	2.72
4	154,369	N/A	133,553	15.25	15.24	131,121	10.00	14.97
5	53,392	N/A	48,354	5.52	5.52	34,685	2.65	3.96
Total	**1,954,860**	**N/A**	**1,476,280**	**240.87**	**156.10**	**1,025,314**	**267.41**	**117.04**

Table 8. Energy Savings and Demand Reduction Realization Rates

ECM	Annual kWh Savings	Coincident Peak kW Reduction	Non-CP kW Reduction
1	77%	129%	92%
2	62%	93%	62%
3	20%	66%	20%
4	98%	66%	98%
5	72%	48%	72%
Total	**69%**	**111%**	**75%**

Application ID 14-1785459
Lighting
M&V Report

November 15, 2016

Duke Energy
139 East Fourth Street
Cincinnati, OH 45201

The Cadmus Group, Inc.
An Employee-Owned Company • www.cadmusgroup.com

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Table of Contents

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Introduction

This report outlines Cadmus' measurement and verification (M&V) activities for three retrofit energy conservation measures (ECMs) as part of the [redacted], Smart $aver custom incentive program application—specifically for replacing metal halide and fluorescent T12 lighting fixtures with LED high-bay lighting fixtures. Energy savings were expected to result from the reduced fixture input wattage and the reduced fixture quantity. Descriptions of the measures as submitted in the original application documentation are provided below.

ECMs: Replace Metal Halide and Fluorescent Fixtures with LED High-Bays

[Redacted] selected to replace the 943 metal halide lighting fixtures and 45 fluorescent T12 lighting fixtures in its approximately 40,000 square-foot distribution warehouse with 277 LED high-bay fixtures. The LED high-bay fixtures have a fixture input of 155 watts. All installed LED high-bay fixtures are listed on the Design Lights Consortium Qualified Products list.

The warehouse operates Mondays through Fridays, from 5:00 a.m. to 6:00 p.m., and Saturdays from 8:00 a.m. to 12:00 p.m. (3,588 hours per year). The annual electricity use for the facility remains unknown at this time due to limited billing data being available; [redacted] moved into the facility in August 2014.

Table 1 summarizes the pre-retrofit and installed lighting fixtures included in the three ECMs.

Table 1. Summary of Lighting ECMs

ECM	Pre-Retrofit		Installed	
	Fixture Description	Qty	Fixture Description	Qty
1	458 Watt Metal Halide	277	155 Watt LED High Bay	87
	2-Lamp, 8-Foot T12 (207 Watt)	45		
2	458 Watt Metal Halide	577	155 Watt LED High Bay	165
3	458 Watt Metal Halide	89	155 Watt LED High Bay	25
Total		**988**	**-**	**277**

Goals and Objectives

Table 2 shows the projected savings goals identified in the project application.

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Table 2. Project Goals

ECM	Application		Duke Energy			
	Annual kWh Savings	Average kW Reduction	Projected Annual kWh Savings*	Claimed Annual kWh Savings	Claimed Coincident Peak kW Reduction	Claimed Non-CP kW Reduction
1	416,402	N/A	440,233	431,131	122.70	38.42
2	825,057	N/A	856,423	835,382	238.69	38.42
3	130,366	N/A	132,351	129,614	36.89	19.21
Total	**1,371,825**	**N/A**	**1,429,007**	**1,396,128**	**398.27**	**96.05**

* Source: DSMore input spreadsheet.

For this M&V project, Cadmus sought to verify actual numbers for the following:

- Facility peak demand reduction (kW)
- Summer utility coincident peak demand reduction (kW)
- Annual energy savings (kWh)
- Annual realization ratios (kW and kWh)

Project Contacts

Table 3 lists the Duke Energy contact who granted Cadmus approval to plan and schedule the site visit for this M&V effort, along with the Cadmus contact and the customer contact.

Table 3. Project Contacts

Organization	Contact	Contact Information
Duke Energy	Monica Redman, Senior DSM & Retail Programs Analyst	monica.redman@duke-energy.com
Cadmus	Christie Amero, Senior Analyst	office: 303-389-2509 christie.amero@cadmusgroup.com
Customer	redacted	

Site Location

The site location is listed in Table 4.

Table 4. Site Location

Address	ECMs
redacted	1 through 3

M&V Option

To assess this site, Cadmus followed IPMVP Option A.

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Implementation

Cadmus reached out to the site contact provided by Duke Energy to review the evaluation plan and to schedule the site visit. Christie Amero of Cadmus performed the site visit on June 23, 2016.

Field Survey

During the site visit, Cadmus met with the facility manager and lighting contractor to review the lighting survey and to collect general operating information. The facility is a furniture distribution center with warehouse spaces, offices, and shipping and receiving areas. The facility operates Mondays through Saturdays, from 7:00 a.m. to 12:30 a.m., year round. The site observes seven holidays per year.

The areas where the lighting fixture retrofit was performed are neither heated nor cooled. There are a few emergency electric unit heaters in the warehouse, but these are only used a couple of days per year to prevent pipes from freezing.

The building was originally designed as a fabric spinning plant and required a high lighting power density. Almost 1,000 450-watt metal halides and 200-watt fluorescent T12 fixtures were used to meet the lighting requirements. There were no occupancy sensors and the fixtures were controlled manually.

After [redacted] moved into the building, the lighting system was redesigned to meet the reduced load. The fixture quantity was reduced to 277 LED high bay fixtures. Two Lithonia Lighting IBH LED fixture models were installed, identical except for their input wattage and lumen output. All of the installed LED lighting fixtures have ceiling-mounted occupancy sensors.

The facility manager confirmed that the lighting levels have decreased since the project was completed, as the site did not need the same lighting level that was used previously.

Field Data

ECMs: Replace Metal Halide and Fluorescent Fixtures with LED High-Bays

After completing the lighting survey, Cadmus performed a walkthrough of the facility to verify the new lighting fixture types and to install light loggers. Figure 1 shows an installed LED high bay lighting fixture in one of the warehouse spaces (left) and the fixture make and model number (right). Figure 2 shows the ceiling-mounted occupancy sensors that were installed with the LED high bay lighting fixtures.

Figure 1. Installed LED High Bay Lighting Fixture

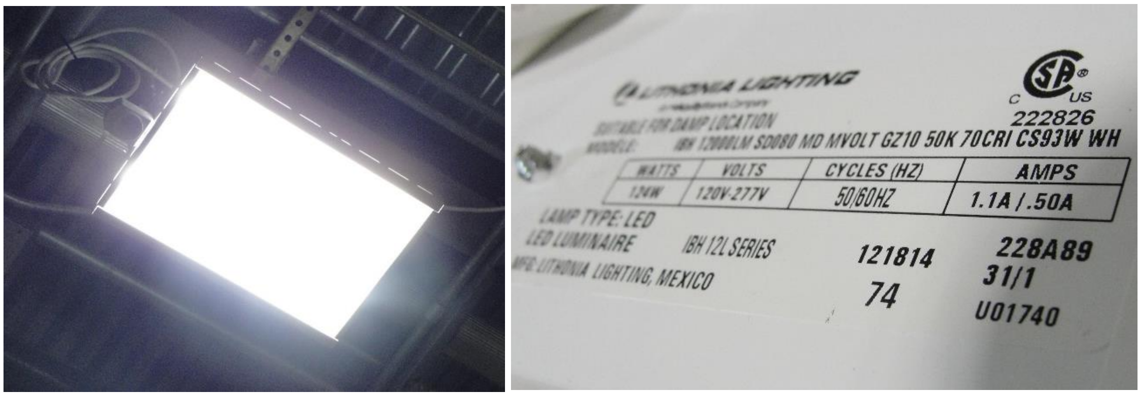

Figure 2. Installed Occupancy Sensors for LED High Bay Fixtures

Cadmus installed 10 light loggers throughout the facility to collect fixture operating hours for a three-week period. Table 5 summarizes the fixture quantities and locations of installed light loggers.

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Table 5. Summary of Fixture Counts and Installed Light Loggers

#	Location	Fixture Description	Light Logger Serial Number
1	Parts Room	LED high bay (2-lamp)	10332061
2	Parts Room	LED high bay (2-lamp)	10380465
3	Parts/Rugs Room	LED high bay (2-lamp)	10162087
4	Parts/Rugs Room	LED high bay (2-lamp)	10327419
5	Rugs Room	LED high bay (2-lamp)	10171984
6	Rugs/Racks Room	LED high bay (2-lamp)	10268180
7	Warehouse/Showroom	LED high bay (2-lamp)	10374216
8	Receiving	LED high bay (2-lamp)	10380621
9	Warehouse/Garage	LED high bay (2-lamp)	10272716
10	FedEx/UPS	LED high bay (2-lamp)	10261711

Figure 3 shows one of the locations where Cadmus installed a light logger.

Figure 3. Light Logger Location #4

Data Analysis

ECMs: Replace Metal Halide and Fluorescent Fixtures with LED High-Bays

Cadmus used the survey and light logger data to verify demand and operating hours for the installed lighting fixtures. Table 6 summarizes the light logger data.

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Table 6. Summary of Light Logger Data

#	Location	Total Metered Hours	Total Operating Hours	Percentage Operating	Average Coincidence Factor
1	Parts	537.9	450.82	84%	88%
2	Parts	532.4	37.73	7%	25%
3	Parts/Rugs	533.5	131.21	25%	79%
4	Parts/Rugs	531.2	32.24	6%	13%
5	Rugs	536.9	122.78	23%	82%
6	Rugs/Racks	537.5	107.20	20%	32%
7	Warehouse/Showroom	537.7	149.46	28%	66%
8	Receiving	538.0	223.53	42%	105%
9	Warehouse/Garage	537.8	228.46	42%	79%
10	FedEx/UPS	535.7	116.42	22%	67%
Average		**535.9**	**160.00**	**30%**	**64%**

The 10 loggers produced a mean projected annual runtime of 2,610 hours. During the three-week metering period, the site produced a mean coincidence factor of 64%. Cadmus assumed that the projected annual operating hours and coincidence factor were equal in the pre-retrofit and installed cases.

The project lighting contractor provided the specification sheets for the installed LED lighting fixtures. All of the installed fixtures are Lithonia Lighting LED high bays, model IBH. Most of the fixtures have an output of 12,000 lumens and input of 123 watts. Only the fixtures in the shipping and receiving areas are 9,000 lumens with an input of 98 watts. Figure 4 shows the lumens and wattages for the selected LED fixtures.

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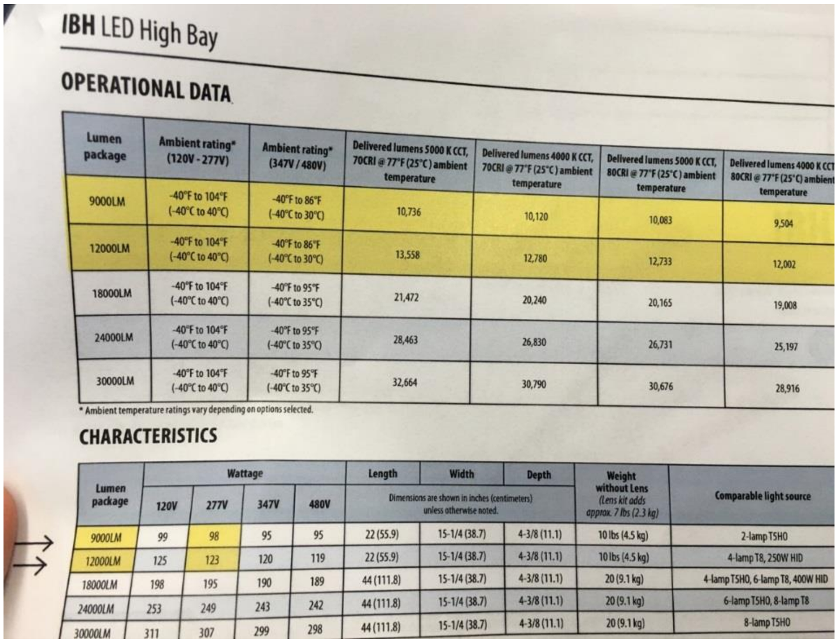
Figure 4. Specifications for Installed LED High Bay Fixtures



IBH LED High Bay

OPERATIONAL DATA

Lumen package	Ambient rating* (120V - 277V)	Ambient rating* (347V / 480V)	Delivered lumens 5000 K CCT, 70CRI @ 77°F (25°C) ambient temperature	Delivered lumens 4000 K CCT, 70CRI @ 77°F (25°C) ambient temperature	Delivered lumens 5000 K CCT, 80CRI @ 77°F (25°C) ambient temperature	Delivered lumens 4000 K CCT, 80CRI @ 77°F (25°C) ambient temperature
9000LM	-40°F to 104°F (-40°C to 40°C)	-40°F to 86°F (-40°C to 30°C)	10,736	10,120	10,083	9,504
12000LM	-40°F to 104°F (-40°C to 40°C)	-40°F to 86°F (-40°C to 30°C)	13,558	12,780	12,733	12,002
18000LM	-40°F to 104°F (-40°C to 40°C)	-40°F to 95°F (-40°C to 35°C)	21,472	20,240	20,165	19,008
24000LM	-40°F to 104°F (-40°C to 40°C)	-40°F to 95°F (-40°C to 35°C)	28,463	26,830	26,731	25,197
30000LM	-40°F to 104°F (-40°C to 40°C)	-40°F to 95°F (-40°C to 35°C)	32,664	30,790	30,676	28,916

* Ambient temperature ratings vary depending on options selected.

CHARACTERISTICS

Lumen package	Wattage				Length	Width	Depth	Weight without Lens (Lens kit adds approx. 7 lbs (2.3 kg))	Comparable light source
	120V	277V	347V	480V	Dimensions are shown in inches (centimeters) unless otherwise noted.				
9000LM	99	98	95	95	22 (55.9)	15-1/4 (38.7)	4-3/8 (11.1)	10 lbs (4.5 kg)	2-lamp T5HO
12000LM	125	123	120	119	22 (55.9)	15-1/4 (38.7)	4-3/8 (11.1)	10 lbs (4.5 kg)	4-lamp T8, 250W HID
18000LM	198	195	190	189	44 (111.8)	15-1/4 (38.7)	4-3/8 (11.1)	20 (9.1 kg)	4-lamp T5HO, 6-lamp T8, 400W HID
24000LM	253	249	243	242	44 (111.8)	15-1/4 (38.7)	4-3/8 (11.1)	20 (9.1 kg)	6-lamp T5HO, 8-lamp T8
30000LM	311	307	299	298	44 (111.8)	15-1/4 (38.7)	4-3/8 (11.1)	20 (9.1 kg)	8-lamp T5HO

This project involved a change in space use (manufacturing to warehouse) and in the required light levels. For this reason, Cadmus could not compare the energy use of the installed, low power density lighting system to the pre-retrofit, high power density lighting system. In order to evaluate the savings, we determined a 'baseline' lighting system design with the same number of lighting fixtures to the installed system. If the site did not choose to install LEDs, we assumed they would have removed or de-lamped a percentage of the pre-retrofit 400-watt metal halide and fluorescent T12 lighting fixtures. Since Cadmus could not verify the power usage of the pre-retrofit fixtures, we confirmed their specific power using technical reference manuals.

The adjusted total pre-retrofit quantity was 277 fixtures, compared to 988 fixtures in the original application (72% reduction).

The evaluated installed case annual energy use was 87,288 kWh. The coincident peak demand was 21.30 kW, and the average annual demand was 9.96 kW.

The evaluated pre-retrofit annual energy use was 323,133 kWh; coincident peak demand was 78.87 kW; and average annual demand was 36.89 kW.

The total evaluated energy savings were 235,845 kWh. The evaluated total summer coincident peak demand reduction (for the month of July, Monday through Friday from 4:00p.m. to 5:00 p.m.) was 57.56 kW, and the average, or non-coincident, peak demand reduction was 26.92 kW.

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Conclusion

While on the site, Cadmus found the equipment installed as expected. The overall energy savings realization ratio was 16.9%, compared to Duke Energy claimed savings. The summer peak demand realization rate was calculated as 14.5%. The average (or non-coincident) peak demand reduction realization ratio was 28.0%.

The evaluated energy savings and demand reduction for this project are significantly lower than the claimed values because the original analysis did not account for the change in space use and load. The original analysis calculated savings as a retrofit project (comparing proposed equipment to existing equipment), but should have been analyzed as a new construction project (comparing proposed equipment to a comparable baseline design that would meet the same load requirements).

Table 7 provides a comparison of the applicant, Duke Energy claimed, and Cadmus evaluated energy savings and demand reduction. Table 8 provides realization rates comparing energy savings and demand reductions claimed by Duke Energy to those calculated by Cadmus.

Table 7. Comparison of Applicant, Duke Energy Claimed, and Evaluation Energy Savings and Demand Reduction

ECM	Applicant		Duke Energy Claimed			Evaluation		
	Annual kWh Savings	Average kW Reduction	Annual kWh Savings	Coincident Peak kW Reduction	Non-CP kW Reduction	Annual kWh Savings	Coincident Peak kW Reduction	Non-CP kW Reduction
1	416,402	N/A	431,131	122.70	38.42	68,099	16.62	7.77
2	825,057	N/A	835,382	238.69	38.42	144,258	35.21	16.47
3	130,366	N/A	129,614	36.89	19.21	23,488	5.73	2.68
Total	**1,371,825**	**N/A**	**1,396,128**	**398.27**	**96.05**	**235,845**	**57.56**	**26.92**

Table 8. Energy Savings and Demand Reduction Realization Rates

ECM	Annual kWh Savings	Coincident Peak kW Reduction	Non-CP kW Reduction
1	15.8%	13.5%	20.2%
2	17.3%	14.8%	42.9%
3	18.1%	15.5%	14.0%
Total	**16.9%**	**14.5%**	**28.0%**